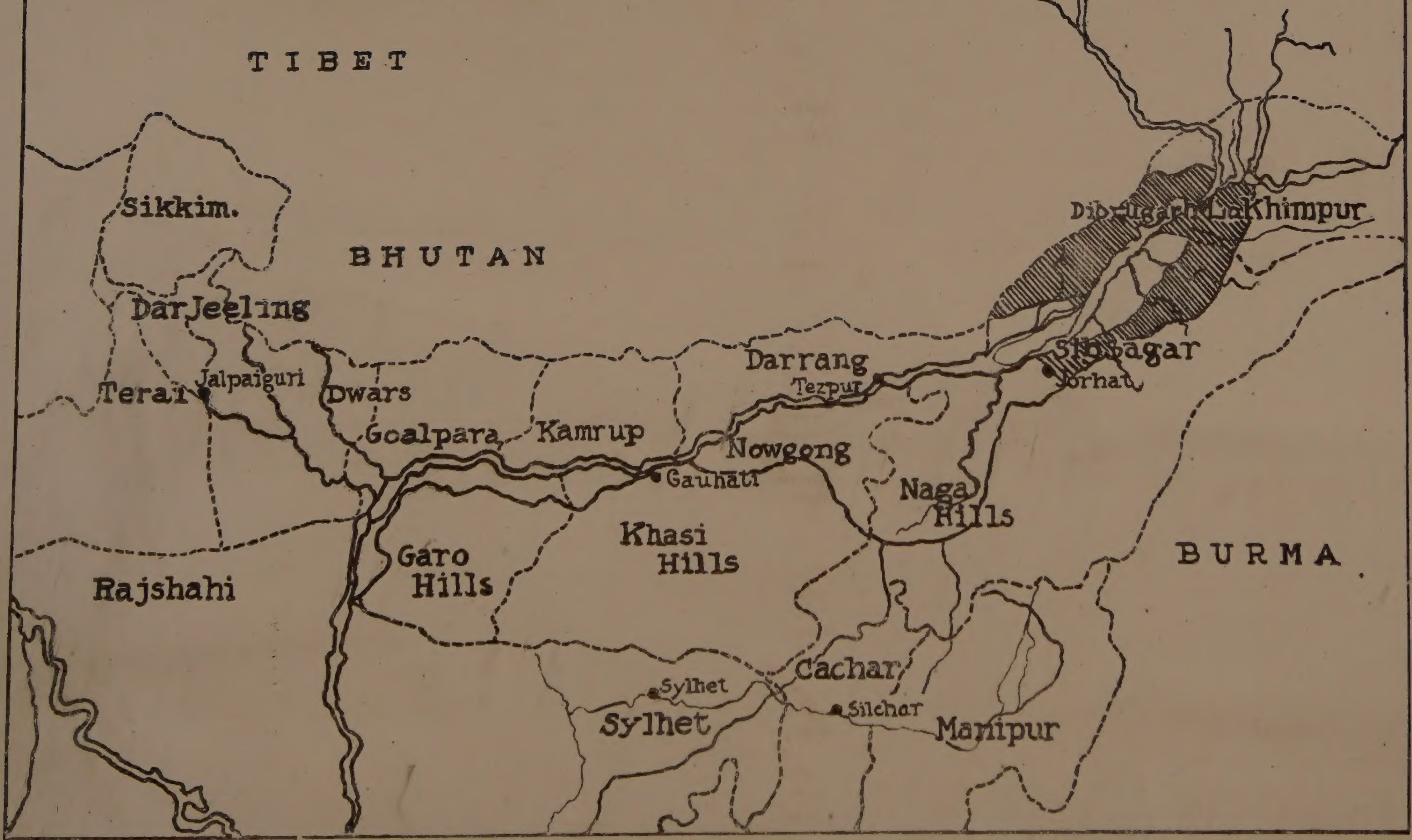
incl.

'On Lasiodiplodia' by T. Petch.

PLATE I.
(Frontispiece.)



Map of the Tea Districts, showing portion (shaded) where Blister Blight occurs.

1906—No. 3.

Indian Tea Association.

THE

BLISTER BLIGHT OF TEA.

BY

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THE BLISTER BLIGHT OF TEA.

The serious outbreak of Blister Blight on tea in Upper Assam, during April and May of the present year (1906), has drawn special attention to a disease which is distinguished by its epidemic character, by the completeness of the destruction which it causes during the short time which it lasts, and by the local character of its appearance. It has been serious in former years. In 1895, Sir George Watt says that he saw hundreds of acres ruined by this blight. Since that time, however, except for a somewhat bad attack in 1900, it cannot be said to have done very material damage, except in individual gardens, until the current year. The present paper is an attempt to place in small compass all that is known of the practical aspects of the subject, including what I have been able to make out during my visit to the affected districts during the attack of April, May and June 1906.

DISTRIBUTION OF THE BLIGHT.

As has already been indicated, blister blight is, so far as we know, entirely confined to Upper Assam. It occurs all over the Dibrugarh and Sadiya Road districts, and is found on both banks of the Brahmaputra, down in the one case to North Lakhimpur, and on the other to Jorhat, and possibly to Golaghat, though I have never seen it in the latter district myself. I have been told that it has been seen in Sylhet, but am inclined to think that it has there been confused with some similar appearance. This limited distribution is a very striking character of the disease, for it is inconceivable that a blight of the intensely infectious character of blister-blight should not be more widely extended if the conditions under which it flourishes, were found in other districts. It appears, in fact, that something exists in these particular areas which is missing elsewhere, and so allows the continued activity of the disease. We shall discuss later what these conditions are.

CAUSE OF BLISTER BLIGHT.

The blight itself has long been known, as it was recorded and an excellent description written, by Mr. S. E. Peal, as far back as 1868. Various other authors spoke in their writings of the 'white blister,' but

until the visit of Dr. (now Sir George) Watt to Upper Assam, in 1895 no careful examination was made of the subject. He, in conjunction with Mr. Massee, of Kew, has shown, conclusively, that the disease is caused by a fungus, which is very analogous to several others doing considerable damage to other plants. Several members of the same family of fungi, for instance, attack rhododendrons, one occurs on grasses, but owing to these and the other plants attacked being of little or no economic importance, the group of fungi has not had very extended study.

The fungus occurring on tea as blister blight has a peculiar appearance which cannot be confused with any other disease to which the tea plant is liable. The most characteristic form is shown in Plate II. Figs. 2 & 3. reproduced from photographs by Mr. T. H. Hall. In this stage of growth it forms raised white circular blisters on the *under* surface of the leaves, which under a glass seem to have 'a floury or mealy texture,' (Peal) and are usually quite circular if they do not involve the midrib of the leaf; if they do involve the midrib, they are on the other hand, generally quite irregular in shape. Corresponding with the white blister on the under surface, there is a bright green circular pit on the upper surface of the leaf* To a casual observer, leaves covered with blisters, such as, those just, described, suddenly appear, without any notice in large areas of tea about the third week in April to the first week in May. The first affected is almost always *unpruned* tea, which quickly takes on an alarming appearance, only realised by those who have seen it. Not content with attacking the young leaves, the fungus rapidly involves the young green flushing stalks, and the blisters grow in size, day by day, until it appears that almost every young leaf will die, and almost every young stalk be ruined. The blight next appears on the remainder of the tea, ruining the first flush stalk and leaves, and making it necessary, in bad cases, for the bush at the end of May almost entirely to make fresh growth right from the level of the pruning. As a result, this not only very seriously curtails the yield of the season, but also renders the wood which afterwards grows on the bushes, permanently weaker than it would otherwise have been. It will at once be seen that the worst effect will naturally be felt on "cut back" tea, where the yield is of less immediate importance than the growth of thoroughly vigorous healthy wood for pruning purposes. The killing down of nearly every fresh green shoot on a heavy pruned bush, by

* In a small proportion of cases these conditions are reversed and the white blister on the under side of the leaf is depressed and the green upper surface raised.

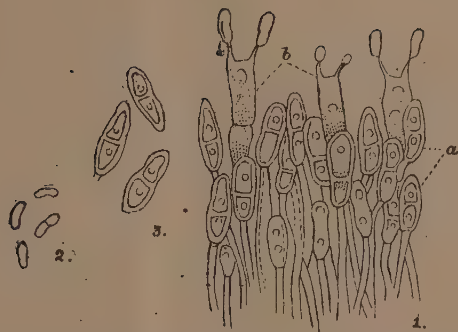

Fig. 1.—(1) Cross section through portion of blister, highly magnified.
(2) Basidiospores.
(3) Conidia.

Fig. 2.—Under surface of blighted leaf, showing blisters. (From photo by T. H. Hall)

Fig. 3.—Upper surface of blighted leaf, showing green pits corresponding to blisters. (From photo by T. H. Hall)

PLATE III.

(To face Page 3.)

Heavy pruned tea attacked with blister blight, showing almost complete destruction of new growth May 1906.

blister blight (see Plate III.,) during the month of May, is one of the most hopeless of sights to be seen in a tea estate.

DESCRIPTION OF THE FUNGUS.

The fungus itself has been carefully described by Mr. Massee. He showed that the history of the parasite, which he named *Exobasidium vexans*, in the tissues of the leaf is somewhat as follows :—The earliest indication of the disease is the appearance of translucent spots on the underside of the leaf, due to the disappearance of the green colouring matter and starch from the cells; this is followed by a rapid increase in the number of the leaf cells situated within the area occupied by the fungus. As this increase in the number of cells occurs, a blister forms, raised above the normal surface of the leaf in order to make room for them. The mycelium of the fungus is very slender and only visible under a very high power of the microscope, but it penetrates all the cells in the blistered area of the leaf. After this mycelium has been growing inside the leaf for some time, it congregates in clusters just underneath the surface of the blister, then breaks this surface and appears under the form of the so-called "white stage," where the whiteness is due to minute, densely crowded, clusters of the fruiting and seeding (spore-bearing) organs of the fungus. These fruiting and seeding organs are well shown in Plate II. Fig. 1, where it is seen that there are produced two different classes of seeds or *spores* (as they are technically called.) The larger ones shown separately in Fig. 1, are called *conidia*, and are composed of two cells with a partition across the middle; the smaller ones shown separately in Fig. 1, are called *basidiospores*, and are extremely minute oval bodies borne in pairs of the ends of special erections termed *basidia*. The former of these types of spores, (the *conidia*) germinate very easily, but it is quite probable, as I shall indicate below, that it is by means of the *basidiospores* that the blight is rapidly spread in an epidemic.

EFFECT ON THE PLANT.

So much for the fungus itself—now let us describe its effect on the plant. The blight is usually first observed by a planter when it has reached the white stage above indicated, and the suddenness with which it then appears on very large acreages all at once gives the idea that the attack is as sudden as the appearance. As a matter of fact, the infection takes place at least a fortnight and probably more before the appearance of the white stage of the blister. This is rendered

certain by several facts, of which the principal is that the white stage is never seen on leaves or shoots less than two to three weeks old. If the younger leaves on a blister blighted section be examined, a much earlier stage of the disease can easily be found. As a matter of fact, in the earliest stage visible to the naked eye the only external appearance consists of a very minute lump on the under surface of the leaves less than $\frac{1}{32}$ of an inch in diameter, with no corresponding depression on the upper side. This lump is a slightly lighter colour than the surrounding leaf, but the difference is small. The fungus, at this stage is wholly internal, and has already been in the leaf from eight to ten days. These minute spots grow gradually day after day, the colour becoming gradually lighter than the surrounding leaf, until in from eighteen to twenty days from infection, and eight to ten days after the blight is first visible to the naked eye, the fungus breaks open the epidermis on the under side and the white stage commences. The fungus does not then cease growing, and the blister may enlarge considerably, but if only the leaf surface is involved it remains circular, (see Plate IV. Fig. 1). If two blisters coalesce, each goes on growing as if it were alone. On the other hand, if the midrib of the leaf or the stalk is involved in the blister, it becomes wholly irregular in shape as shown on another leaf in Plate IV. Fig. 1, as the fungus can progress very much faster up and down the stalk or midrib than in the regular texture of the leaf.*

If the blister is near the base of the leaf and so interferes materially with the food supply of the remainder of the leaf, this latter begins to turn brown and die, and the same occurs when the stalk is affected. When the blister completely encircles the stalk in the latter case, the whole shoot above the affected point dies. By the time the growth of the shoot is affected materially by the existence of the blister, the stalk has usually developed two or three younger leaves. This means that the whole of such new growth is ruined and destroyed.

WHERE THE BLIGHT COMES FROM.

Two very important questions now arise of great practical importance. The first of these is as to how infection takes place; the second as to where the fungus lives during the remainder of the year. Let us take the second point first. In one of his publications, †Mr. Massee

* This description is of the blight as it appears on young leaves. On old leaves the blisters are usually smaller and never grow to the size as young leaf. See Plate IV Fig. 2.

† Text book of Plant Diseases, London, 1899.

PLATE IV.
(To face Page 5.)

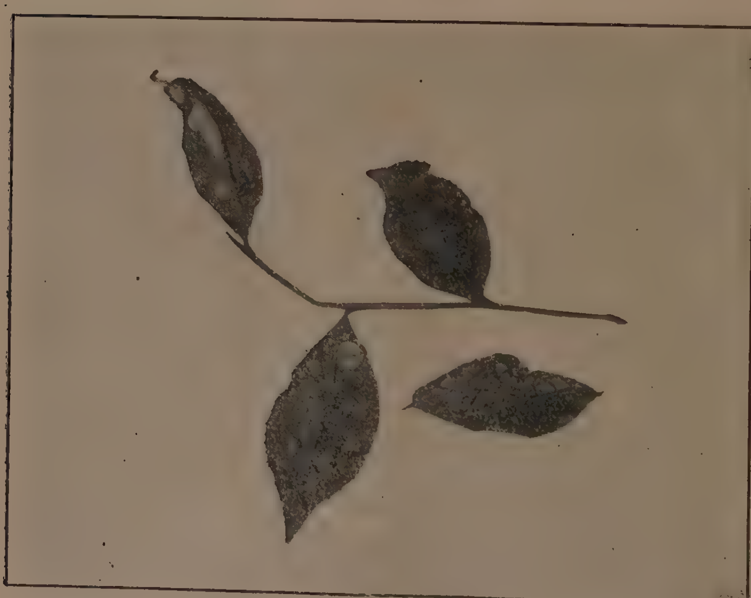

FIG. 1.—Blister blight on young tea shoot: also leaf nearly covered with blisters May 1906.

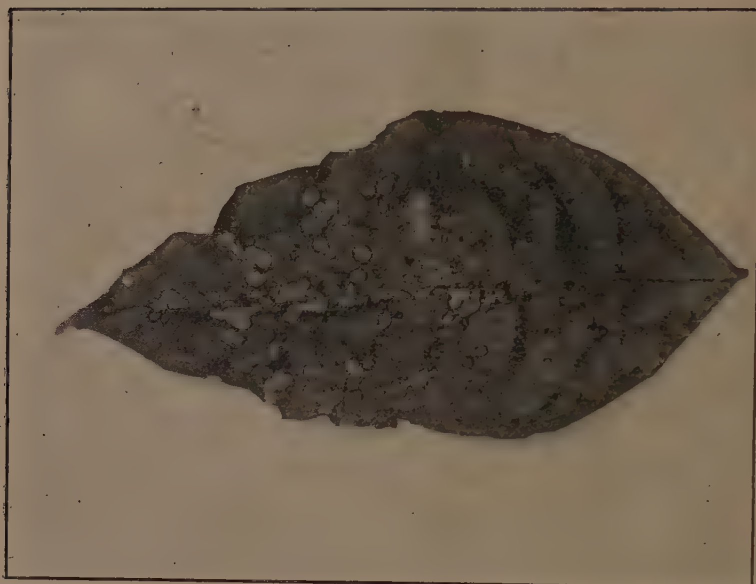

FIG. 2.—Blister blight on old leaf, about two thirds natural size. May 1906.

suggests that the fungus is perennial in the branches of the tea bush, and 'produces the first crop of spores the following season which are carried by the wind to the pruned bushes.' The basis for this suggestion is the undoubted fact that in a garden where unpruned tea exists, this is nearly always the first attacked and forms apparently the centre of distribution of the disease. This fact can be otherwise explained, and I have found no further evidence whatever that the disease is perennial in the branches of the tea bush, and can say with confidence that such is not the case. On the other hand, there is a good deal of evidence to show that while the blight always disappears, as an epidemic, by the beginning of June, yet during the whole of the year there are occasional leaves on the tea which carry the blight. I have found such in November at Noholia in the Dibrugarh district, and am told that during last pruning season (December, January and February), leaves with living blisters were found and destroyed on one of the gardens which have been badly attacked during the present season. Now as unpruned tea retains the whole of its leaves during the cold weather, if only a few of these carry, as they do, the fungus, this is sufficient to account for the outbreak originating in this part of a garden, without any supposition (for which there is no other evidence) of a perennial mycelium in the branches.

On examination of the blisters found in November the curious fact was noticed, which may have been a regular thing or no, that the *basidiospores* appeared to be absent at that season. If this is always the case, and if the *basidiospores* are only produced in the spring season, it accounts for the blight only becoming epidemic at one time of the year, namely in April and May. The observation needs confirmation, however.

I haye spoken of leaves of tea being affected sporadically with this fungus at all times of the year, and thus carrying on the fungus from season to season. This is not the only means by which it may be perpetuated. Other plants are attacked by a fungus which cannot be distinguished from that affecting tea. The garden Croton (*Codiæum variegatum*) is often affected in Upper Assam, and this throughout the year. Mr. A. Crowe, of Talup, informs me also that he has seen the fungus on the '*nahor*' (*Mesua ferrea*) tree. In the case in which he noticed this he writes:—The Nahor was a stunted tree that had had the top broken so that it branched very low, and its branches intermingled with the tea. The tea under its shade was a mass of blister, and the leaves of the Nahor were also covered with what I

had not the slightest doubt was blister blight, but it took a rather different form, which I attributed to the fact, that the leaf texture of the two plants is so different. The Nahor leaf is very hard, and the blister took a warty form irregular in shape and not the quite round pock mark as usually on tea. On the upper surface the wart was a pale green, on the lower a dirty yellow.' By an accident in the post I have not been able to check this by microscopic examination, and at present there is no more to be obtained, but I hope soon to make certain of the identity of the *nahor* and the tea blights.

In summary, we may say, that sufficient data are to hand to indicate that at all times during the year there are a few leaves in a tea garden affected with the blight, quite sufficient to ensure its being carried from season to season. And beyond this there are a few jungle plants, though not many, which are also affected and which would account for the distribution of the blight to new centres.

HOW INFECTION TAKES PLACE.

The other important practical point I have mentioned is to ascertain how infection takes place. There is really little doubt in the matter. As the spores ripen on an existing blister, they are dislodged by the wind and carried to another leaf or stalk on the same or an adjoining bush. If they lodge on the under side of the leaf and the latter is wet or becomes wet shortly after, the spore germinates, puts forth a very minute thread which enters one of the stomata or breathing organs on the leaf and grows inside as described above, when the infection is complete. If the spores lodge on the upper surface of the leaf and this becomes wet, they germinate, but find no means of entrance into the leaf and so die. If the leaves do not become wet within a certain time (not yet determined) the spores die in any case without germination. The fact that these spores are carried by the wind is rendered extremely probable by the position of the blighted leaves on an affected bush, and also by the gradual way in which as a rule the attack radiates from a centre of distribution in the garden. Usually this centre is a block of unpruned tea, and although there will be sporadic cases all over the garden yet such unpruned tea can generally be recognised as the centre of distribution.

SUMMARY.

The principal facts which we have made out relatively to the disease, so far appear to be—

(1) that the blight is caused by a fungus.

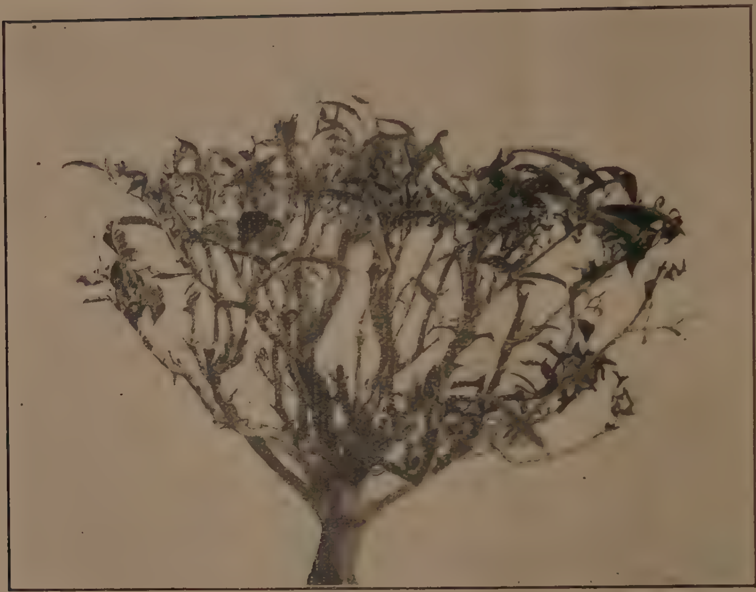

FIG. 1.—High pruned tea badly attacked with blister blight. Showing almost complete destruction of young growth. May 1906.

FIG. 2.—Tea attacked with blister blight the year after heavy pruning showing destruction of young growth. May 1906.

(2) that this fungus can be found sporadically on tea leaves throughout the year, but only becomes epidemic from April to June.

(3) that the infection is carried from season to season by these sporadic leaves and plants affected, as well as probably by some jungle and garden plants.

(4) that the fungus is carried by the wind, and appears to germinate only on a wet leaf or stalk.

(5) that it takes about ten days from germination to become visible on the leaf, and from two to three weeks to reach the white stage.

EFFECT OF SEASON.

The blight usually, if not always, is worst in a season in which there is a large rainfall in February, March and April, coupled, as it usually is, with a temperature lower than is usual for the season. That this is the case in the Sadiya Road district is shown by the following figures for rainfall, kindly supplied to me by Mr. C. Pringle, Superintendent of the Doom Dooma Tea Co.

	1896.	1897.	1898.	1899.	1900	1901.	1902	1903.	1904.	1905.	1906.
January	0·93	1·44	0·73	0·75	1·74	1·95	1·51	1·92	1·26	1·65	0·96
February	1·25	2·16	2·24	1·57	3·93	2·94	3·07	1·24	1·82	0·85	3·83
March	6·33	7·41	2·12	5·06	7·03	1·77	5·39	5·22	7·92	9·06	10·60
April	11·58	5·45	12·07	9·53	15·13	16·45	13·52	10·60	16·60	7·73	25·52

Now the two years in which great damage was done by the blight were precisely 1900 and 1906, when a high rainfall for February was followed by a high rainfall for March. In 1901, there was a large amount of rain in February, but a drought in March : in 1902, which is the only other year with a large February rainfall, there was a moderate fall also in March, and in that year an attack did occur, but not of sufficient proportions to cause material anxiety.

The intimate connections between early rainfall and blister blight is rendered almost certain by considering the close of an attack, and the immunity of other districts.

The close of an attack invariably coincides with a period of hot fine sunny weather. During the present season the gardens in the affected districts on May 20th were covered with a large amount of fresh actively growing young blister and the outlook seemed extremely serious. About that date, however, the continuous wet cloudy weather which had persisted up to that time broke, and a period of hot, sunny weather ensued. Day by day the number of young and fresh blisters

to be found became less and less, and the then existing blisters dried up, and after about ten days it was difficult to find a blister in the early stages on the bushes. An experiment was made by placing a leaf carrying a white soft actively growing blister in the sun with the leaf stalk in water. In two or three hours the blister was drying up completely though the leaf itself was vigorous and turgid. Although a period of wetter weather succeeded the hot weather at the end of May, there has been no renewal of the blight, and past experience indicates that such renewal is not probable.

IMMUNITY OF OTHER DISTRICTS.

The immunity of other districts is probably due to similar reasons. It is well known that the only tea district (with one exception) which usually receives substantial rain every month from January to May is precisely the district in which this blight is found. This is indicated by the average rainfall returns for a very large number of years for a good many stations in or adjoining the tea areas of North-East India as follows :—

	Oct.	Nov.	Dec.	Jan	Feb.	March	April	May	Annual Total.
	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.	ins.
Dibrugarh	6·05	1·11	·83	1·49	2·53	5·54	9·84	14·18	112·11
Sibsagar	5·17	1·11	.59	1·14	2·16	4·74	9·88	11·47	94·35
Nazira	5·11	·91	·66	1·27	2 27	4·81	9·27	9·97	89·06
Tezpur	3·36	·72	·50	·59	·90	2·43	6·08	9·68	73·08
Nowgong	3·67	·49	·28	·77	·98	2·44	5·43	9 12	77 10
Gauhati	2 99	·52	·24	·60	90	2·47	6·20	9·96	67·19
Silchar	6·40	1·31	·54	·64	2·32	7·93	13·56	15·72	121 43
Chittagong	6·41	1·49	·58	·41	1·16	2 14	4 47	9·68	105 09
Jalpaiguri	4·78	·14	·07	·48	·39	1·47	3·63	11 84	125 72
Buxa (Duars)	10 19	·67	·65	1·10	1·02	2·80	8·70	20·24	208·61

Now of all these it will be seen that the three stations in the affected districts (Dibrugarh, Sibsagar and Nazira) are the only ones, with the exception of Silchar, which possesses a spring rainfall such as to encourage the blight, if my explanation of its being confined to these districts is correct. In Cachar, however, the blight does not occur, although the above figures would seem to indicate conditions favourable to it. The reason of this is, probably, that though the *averages* are as above indicated, yet the individual years are much more variable than in Upper Assam, and while a drought may happen one year, the next season may have a very large spring rainfall. This variability would seem to be possibly as great a hindrance to the blight as a drought each year.

To the former conclusions (page 6 and 7) we may therefore now add the following ;—

(1) That the prevalence of blister blight in any one year is due to a wet February being followed by a wet March and April.

(2) That the exclusive continuance of the disease in Upper Assam may be attributed to the regular spring rainfall in that district, which while not always enough to produce an epidemic, is always enough to secure the continued life of the fungus.

POSSIBLE METHODS OF CURE.

We may now turn to the possible preventive and remedial measures against the serious blight which has been described. It will at once be seen, in an epidemic disease like this, the progress of which is very rapid, that any attempt to cure the disease after it attacks a block in a tea garden, is not likely to be attended with much success. Two methods have been suggested in the past but, as would be expected, they have not been at all successful. The first of these is the recommendation that when the blight is first seen, all affected leaves and shoots should be plucked off. This has been done in quite a number of cases, but it has almost invariably been stated by the planters, that the blight gets ahead of the pluckers at once, and that the method is useless. The same record has been made by men who have tried the system during the present season, and it is really only what might have been prophesied. When the white blisters appear, the blight has been in the leaves and shoots for at least ten days, and the infection has almost certainly already spread far beyond the area in which the white blisters are occurring at the time. I cannot recommend that money and labour should be used in the useless occupation of removing the leaves.

I had at one time the hope that by spraying the block, on the first sign of an attack, with Bordeaux Mixture it might be prevented from spreading further and this would probably be the case if the blight was noticed at its first onset. But it never is noticed and is never likely to be noticed until the white stage appears, and then it has spread far beyond the block on which the spraying is done. And moreover, the new growth after the spraying will get the disease perfectly easily, in spite of the remainder of the bush being covered with Bordeaux Mixture. I saw some bushes in May this year, which had been sprayed three weeks before with Bordeaux Mixture, and much

of which remained on the bushes, on which the new leaves were covered with young blisters. I am afraid that Bordeaux Mixture or any other spray (for Sulphide of Potassium, and Blower's sulphur solution have been suggested) has no place in the cure of blighted areas of high pruned and mature tea. Dusting bushes with sulphur or with lime stands in the same category. The latter might well prevent the distribution of spores and so be very valuable, but as a curative agent this year's investigations leave little doubt that it is useless. In cases where it has been supposed to be effective in curing the blight, it is most probable that the epidemic was passing off before the lime was dusted on the bushes.

PREVENTIVE MEASURES.

The use of preventive measures seems to offer more possibilities and it is certainly the only way of tackling the blight, if it can be tackled at all. But we are here met with the difficulty that the disease is extremely erratic in the selection of the blocks which it will attack. The fact, that a particular piece of tea has been affected one year, is no reason for thinking that it will be seriously attacked in the next season. It is quite as likely that the worst affected area will be in quite a different part of the garden. Thus no method of prevention by spraying is practicable in general, because to protect the whole garden would mean to spray it all, which is impossible on account of the cost. There are certain special cases, however, in which spraying is called for.

The first is the case of nurseries, which are often very badly damaged if not completely ruined. The area involved is usually so small that I would be inclined to recommend spraying every month from February to June with Bordeaux Mixture. The mixture should be made precisely as for treating Red Rust, * and applied in the same manner. As well as preventing an attack of blister blight, this will cause the seedlings to be free from Red Rust, often an even more important matter. The repeated application is to protect the younger portions of the plant which are always attacked by the blight.

The other case where spraying is valuable, is with cut down or cut back tea. This tea, as I have already described, is the most

* Dissolve three pounds of Sulphate of Copper in 23 gallons of water in a wooden tub, not in a metal vessel. In another vessel slake 3 pounds of quicklime, if possible freshly burnt, in two gallons of water. The lime should form turbid smooth liquid without any lumps. Finally add, gradually, the lime liquid to the Sulphate of Copper solution stirring meanwhile. When thoroughly mixed, the liquid is ready for use but should be kept stirred up.

seriously attacked of all on a garden if judged by the damage done by the blight. It would pay well in a garden liable to the blight to spray this area monthly from February to May, so that new growth would always be treated within a short time of coming out. The time from the middle of March to the middle of May is the most important, for at this period the infective power is usually most active and the more often the bushes can be sprayed in this period, the safer the block will be. Seeing the extreme import for the future of the bushes of getting good strong growth on cut back tea, no reasonable expense should be spared in ensuring its immunity from this blight. Still this must be considered as a preventive measure, and not as a cure. If a planter waits till the blight appears before spraying probably it will be found to be too late.

PRECAUTIONS AGAINST THE BLIGHT.

Two other precautions can be recommended on a tea estate. The first is the avoidance of unpruned tea; the second the removal of all leaves diseased in any way at the time of pruning.

Opinions differ very much as to the advantage to be gained by leaving tea unpruned at any stage of its life, and as a rule it is only now done the year following serious heavy pruning. Whether even this is advisable is at least doubtful, and the case against the practice is much strengthened in the districts affected with blister blight by the fact that the unpruned blocks become the foci of infection for the garden. That they were the centres of infection during the recent epidemic admits of no doubt. It was noticed on every garden where such tea existed, and the reason why they should naturally be the centres of infection has already been explained. As a result one may say that in the blister blight districts tea should be left unpruned as rarely as possible and then only for some reason which is of greater importance than the risk of blister blight.

The pruning of the tea in Upper Assam is usually very good and very clean. But following on the pruners there should be, on every property, a gang who would pluck off and *carry away* all the diseased leaves which they can find on the bushes after pruning. At the same time all the prunings should be got rid of either by burning or by burial as speedily as possible before any disease on the part pruned is able to infect the leaves left on the bushes. As I have shown that the blight occurs sporadically the whole year through on the tea, I cannot exaggerate the importance of the removal and burning of all diseased material during the cold weather.

SHADE AND BLISTER BLIGHT.

The relation of shade to the disease remains to be dealt with. The blight is without doubt, very fond of darkness and damp, and gardens very closed in with jungle or filled up with ordinary forest trees have been, in the past, particularly liable to it. But, on the other hand, it cannot be said that *slight* shade has any effect on an attack at all. The garden most seriously affected this year in the Sadiya Road district was one which has hardly a single tree on it, and one whose surroundings, in addition, are quite open. On individual gardens possessing avenues of Grevillea trees, but otherwise free from shade, the blight was not worse under these avenues; nor were blocks planted with *sau* trees *(Albizzia stipulata)* any worse (but rather the other way) than those not so planted. In the latter case this was perhaps to be expected, seeing that the *sau* tree is leafless during the whole time when the epidemic of blister blight is taking place. Apart, therefore, from such shade as prevents free circulation of air and darkens the plants, there is no evidence that trees among the tea or round the tea cause the blight to be worse than would otherwise be the case. I should, however, be strongly opposed to planting trees with heavy foliage darkening the tea in and round the blocks in districts liable to be affected with blister blight.

'JAT' AND BLISTER BLIGHT.

While it cannot be said that any *jat* or variety of tea is immune from the disease, yet there seems little doubt, that they differ materially in susceptibility. Hybrid blocks were usually least attacked, and the higher Assam indigenous types perhaps the most. Between these two extremes the same type seems to differ in susceptibility according to its position and treatment. 'Manipuri' in some places was almost immune; in others it seemed almost as much affected as the best *jats* of Assam. Beyond these notes no data exist which enable me to find any relationship between the variety of tea and the susceptibility to the disease.

VIGOUR OF BUSH AND BLISTER BLIGHT.

But one thing appears certain in most of the moderately attacked sections. The least healthy and vigorous bushes were almost always those to contract the blight first, and the best plants were generally least affected. As I have again and again insisted with other diseases, susceptibility, in most cases (thread blight is an exception) depends at least in a measure on the healthiness of a plant, the healthier being

the more resistant. This is certainly the case with blister blight, and the fact adds another argument to those I have often cited before to urge the importance of bringing every bush to the standard, if possible, of the best bushes in a block. This may not always be possible, but by special treatment, by special individual manuring and other methods, an attempt should be made to raise the standard of resistance to disease of every plant to that of the best plants in a section.

CONCLUSION.

The blight with which this report deals is in its immediate effects perhaps the most alarming to a planter of any that attack the tea bush. It comes on suddenly; it spreads very quickly; it kills the shoots which are to form the basis of the season's crop or on heavy pruned tea of the future bush; it reduces the yield considerably, when bad, in the months of the year when the best tea is made; and apparently the planter is helpless in face of it. I have shown, however, that the blight is the result of well-defined causes, that it can almost certainly be prevented from doing serious damage on the heavy pruned tea, where its damage is most serious, by well-known means; and that, in the future, knowing the life history of the fungus which causes the blight, we may hope, if regular care in prevention be taken, to see the disease no longer the menace that it has been during the present season.

[C. P.—1,000—18-7-1906.]

1910—No. 3

Indian Tea Association

THE

OUTBREAK OF BLISTER-BLIGHT ON TEA IN THE DARJEELING DISTRICT IN 1908-1909

BY

W. McRAE, M.A., B.Sc

MYCOLOGIST TO THE GOVERNMENT OF MADRAS

CALCUTTA
THACKER, SPINK & CO

1910


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PLATE I.

Tea leaves and stems affected by Blister-Blight.

Fig. 1. Shoot of tea affected with Blister-Blight.

Fig. 2. Same showing the red tinge.

Fig. 3. Same showing the hypertrophy of the leaves and the upper flushing buds killed off.

Fig. 4. A cut-back seedling badly affected.

Fig. 5. Same with all the leaves and buds killed.

NOTE.

The following Report on the outbreak of Blister-Blight in the Darjeeling Tea District in 1908 and 1909, by Mr. W. McRae, M.A., B.SC., now Mycologist to the Government of Madras, first appeared in the *Agricultural Journal of India*, Vol. V, Part II. It forms one of several valuable contributions to the scientific knowledge of tea which have reached us from the Imperial Agricultural Research Institute at Pusa, where Mr. McRae was acting as Officiating Mycologist when he carried out the work described in this article. The Scientific Department of the Indian Tea Association has not on its staff a professed Mycologist—one who has made a special study of lower forms of plant-life, more particularly Fungi, and is competent to work out their life-histories and study in full detail a certain large class of plant diseases. Consequently it has frequently been necessary to appeal to the Imperial Mycologist whose assistance has always been readily obtainable, and the more complicated cases of disease of the tea plant have been handed over to the expert handling of his department.

Our thanks are due to the Inspector-General of Agriculture who has kindly permitted this article to be reprinted in its present form, and to Mr. McRae, the author.

G. D. H.

THE OUTBREAK OF BLISTER-BLIGHT ON TEA IN THE DARJEELING DISTRICT IN 1908-1909.

By W. McRAE, M.A., B.SC.,
Mycologist to the Government of Madras.

In June 1908, near the head waters of the Balasan River, leaves of the tea plant were observed to be attacked by Blister-Blight. Gradually the blight spread from garden to garden, and in October it was noticed on gardens on the Tukvar slopes. This was the first appearance of blister-blight in the district of Darjeeling. The disease is not a new one on the tea plant, but hitherto it has been confined to the Brahmaputra Valley in Upper Assam, where it was investigated and described by Sir G. Watt in 1895. It has existed in that region for over 40 years. These two places are widely separated, yet the blight has not been reported from any of the intervening tea districts of Cachar, Sylhet or the Duars. In this year it did not do much damage and in the cold weather died down.

In 1909 the blight appeared again but earlier in the season, *viz.*, in March. During the summer it showed for the first time on other gardens. Everywhere it spread rapidly till hardly a garden in this part of the district is now free from blight.

The first indication of a blister is a small, pale green, yellow, or pinkish translucent spot easily seen against the darker green of the rest of the leaf when it is held up to the light. Sometimes the pinkish tinge fades or it may never be discernible. In other cases the spot is deep red on both sides like red ink, and the red tinge remains even when the spores are ripe. The circular spot enlarges, usually reaching a diameter of $\frac{1}{4}$ to $\frac{1}{2}$ inch. On the upper side of the leaf the spot gradually becomes depressed into a shallow cavity and on

the under side it bulges out slightly, thus forming the blister from which the blight takes its name (Plate II, figs. 2 and 3). The upper concave circular area is smooth and shining and the colour is usually paler than the rest of the leaf. The under convex surface, on the other hand, is dull and at first is grey as if dusted with white powder, but when mature it becomes pure white. The lower surface produces colourless spores which with the outgrowth of fungus filaments give the white appearance to the under side of the blister and on some vigorously growing blisters slightly to the upper side also. In not a few cases the form of blister is reversed and both forms may be found on the same leaf; but the spore-bearing surface is always principally on the under side of the leaf. After a time the white blister becomes discoloured till it is dark brown or black, then it becomes dry and shrinks till the discoloured patch is in the same plane as the rest of the leaf.

After the leaves of a bush have been attacked, the disease spreads to the leaf-stalks and the young, succulent, green stems, but here the appearance of the disease is not so conspicuous though the damage is much more serious. The course of the disease on the young delicate stem is like that on the leaf, only no blister is formed. The colour of the spot is very similar, but the deep red tinge is wanting. The spot becomes elongated and also gradually spreads round the stem. At this place the stem becomes slightly swollen. When the spores are ripe, they give a grey appearance to the spot, but it does not become pure white like the blister. The disease eats through and the leaves and buds on the green stem above wither and blacken. while the stem bends over and falls off at the diseased part. Several of these dead twigs on a bush give it a black, unsightly appearance.

When a thin section of a blister is looked at under the microscope, fine colourless threads (hyphæ) of the fungus are seen between the cells of the leaf. These come to the surface on the white side of the blister and produce spores at their ends. There are two kinds of spores. The first is two-celled and is

PLATE II.

FIG. 1.

FIG. 2.

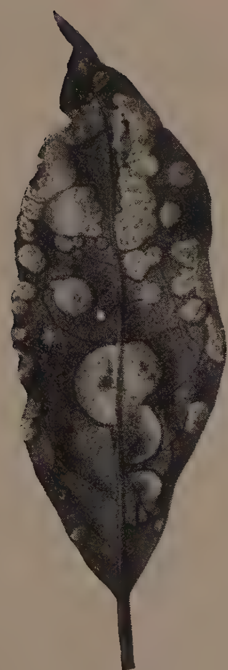


FIG. 3.

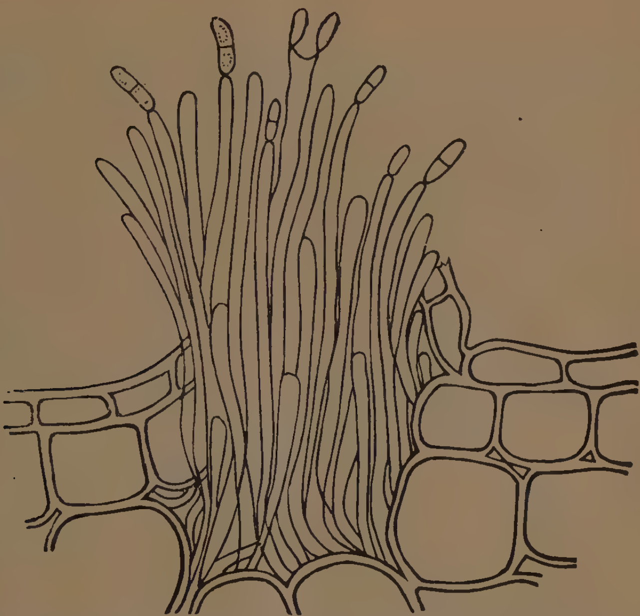
I. T. A.

BLISTER-BLIGHT OF TEA.

(Exobasidium vexans, Massee.)

Fig. 1. Shoot of a tea showing the upper part bending over at the affected spot on the stem.
Fig. 2. Upper side of a blistered leaf showing the concave spots. From a photograph.
Fig. 3. Under side of a blistered leaf showing the convex spore-covered surface. From a photograph.

produced at the end of a long stalk. The second kind is one-celled and is produced on a very short, thin stalk from the swollen end of a hypha. In the latter case spores are always produced in pairs.



Section of a small part of a leaf of the tea plant showing the hyphæ of the fungus bursting through the surface of the leaf and bearing (1) two-celled spores singly and (2) one-celled spores in pairs.

When kept in a moist chamber on a slip of glass or on the surface of a fresh tea leaf the spores swell slightly and germinate within $5\frac{1}{2}$ hours of being sown. From each of the cells of a two-celled spore or from the one-celled spore a thin tube grows out, increases in length and enters the leaf by a breathing-pore. When inside it branches freely and gets its nourishment from the cells of the leaf. After a period of eleven days the translucent spot is clearly visible and in from six to eight days more the blister is formed and the hyphæ produce spores.

If a blister is situated on the midrib, the leaf often folds or rolls upon itself irregularly, sometimes the lower and sometimes the upper surface of the leaf remaining outermost. If several blisters occur near the margin, the leaf often becomes curled and twisted in the most fantastic manner. The number of

blisters on a leaf varies from one up to about twenty, and they may be isolated or several may run together to form a large patch with an irregular outline. To such an extent does this sometimes go that the whole under surface of the leaf may be covered with an even mass of blisters.

When many of the leaves on a bush have even only a few blisters each, the damage done to the bush in reducing its green surface available for food-making is great, and in addition the parasite is draining the host bush of the nourishment made for it by healthy leaf tissue. When the vitality of the growth is lowered, the healthy flushing of the young leaves and buds is retarded, causing considerable loss. When the disease runs unchecked through a bush and the young shoots have fallen over and decayed, it has a black, unsightly appearance quite justifying the anxiety of the managers on those gardens where the disease is prevalent.

The exact place in the district where the disease first occurred cannot now be settled with certainty, but it was most probably on the slopes on the southern side of the Senchal ridge. Last year it was noticed at several places near the head waters of the Balasan River almost simultaneously. After it had once been reported, it was found on quite a number of gardens. From this it may be conjectured that the rate of dissemination of the disease was very rapid, or that it may have existed in the gardens for some time without having been noticed. This last may quite well have occurred in gardens where it was doing little real damage, especially as the disease was new to the district and was then unknown to many planters. From observations made this year the former also seems to be the case, and when once the blisters have matured, the spores, which they produced, quickly become distributed.

When blister-blight appears on a block, scattered bushes are affected, some badly and others slightly. Only one or two leaves on a bush or a few more or a great many are blistered. A block may appear quite healthy till suddenly a few blistered leaves will be seen, and this occurs in a noticeable way when a spell of wet

PLATE III.

I. T. A. TEA BUSH AFFECTED BY BLISTER-BLIGHT.

Tea bush affected by Blister-Blight. From a photograph by Mr. Claud Bald, Tukvar. The surrounding bushes have been blocked from the background.

weather recurs after a few days' sunshine. Little damage may be done or the blight may become worse and worse, both mature leaves and flushing shoots becoming affected, then blackening and dying till leaf-picking is stopped.

The spores of the parasite are distributed by the wind and the quick distribution can be understood when one remembers the fairly strong breezes that occur here. On days in which there are a few hours of dry weather or sunshine, the wind will blow the light dry powdery spores about, and they may be borne a considerable way and scattered over a comparatively wide area. In the Balasan Valley strong breezes blow up the valley, especially in the evening of a hot day, and the blight has travelled much more rapidly and is more severe towards the head waters than downwards towards the plains. In this valley the disease is severe on slopes exposed to the wind, *i.e.*, on southern slopes. On the Tukvar side of Senchal the winds are not so steady and are more irregular in direction, and here the distribution of the disease is erratic.

The blight attacks the high quality Assam and hybrid jâts most severely, while China and Manipuri are not so much affected. It is quite interesting to see, in some China blocks where Assam or hybrid bushes have been used to reset empty places, how the leaves of the two high quality jâts are well infected with blister, whereas the leaves of the China are almost free. Yet in some gardens China is very badly affected and the bushes have a woeful white or black appearance according to the stage of the disease.

With respect to heavy pruned, lightly pruned and unpruned tea it is difficult to say definitely that one is attacked more often than another, but, when once the blight has come, the damage done is in the order of mention. In the young, succulent rapidly-growing leaves of heavy pruned tea the blight develops vigorously and may destroy nearly all the leaves that ought to go to form growth leaves. Now for a good framework of new wood a heavy pruned bush depends mainly on the growth made in the first year after heavy pruning. If then in the first season much damage is

done to the leaves, growth is checked, thus causing serious loss in crop in the following season.

The blight is worse on places with a high rainfall and worst about that elevation where rain falls nearly every day and mists are constantly hanging about. Thus on the slopes of the Rungbang and Balasan Valleys facing the plains the blight is on the whole worse than on the Darjeeling side of Senchal. The blight seems to be more severe at high elevation and worst between 4,000 and 5,500 feet. Not elevation, however, but moisture is the real factor with regard to severity. In this district high elevation means, within certain limits, high and evenly distributed rainfall. The three worst blocks and the only extremely bad cases on a large area seen by me were on gardens between 5,000 and 5,500 feet. Whereas in a low elevation garden in the Rangit Valley, the blight came late in the season of 1909 and was only very slight; one had to search to get blistered leaves. Too much shade, whether artificial from planted trees or from proximity to jungle, favours the blight and it is worse too on damp, shady hollows. It was found that the bushes under the trees grown for shade in the garden were often affected when the surrounding unshaded bushes were free from blight, and when both were affected the shaded bushes were more severely blistered. This occurred under old trees that were giving more shade than was really necessary, and suggests the thinning of jungle trees near the tea and lopping off branches where shade-trees have become too dense.

The amount of damage done by blister-blight this season is difficult to gauge. Fortunately for the industry, weather conditions were favourable from April to June and gardens flushed well, getting thus well ahead of their usual average. They have, however, since gone down and some gardens are well behind. The greater loss is attributable to wet, unfavourable weather in July and August and a considerable portion to blister-blight. The worst damaged piece of tea was a heavy pruned block. Ninety per cent. of the plants had lost all their leaves or the leaves were all blistered. As soon as a bud sent forth a leaf, it was attacked.

PLATE IV.

I. T. A.

EXOBASIDIUM ON SYMPLOCOS THEÆFOLIA.
Exobasidium on Kharani (*Symplocos Theæfolia*, D. Don).

The year's growth had failed, and most of the bushes will start next spring as if they had been just pruned unless, as is more likely, they start weakened by the lack of growth this season. In new-extension young plants often suffer badly (see Plate I, figs. 4 and 5). In one seed bed, all the seedlings were destroyed by blister-blight, and as the cost of the seed and of upkeep amounted to Rs. 770, this was a dead loss. On Dooteriah Division in the two seasons over 900 maunds of blistered leaves were picked and destroyed, of which about one-sixth might have been made into tea, the remainder being mature leaf. The cost of collecting this amount of blistered leaf was Rs. 657. At Tukvar the loss this year is about 30 maunds of tea. These are average examples of loss, but some gardens have lost much more and others much less. No account has been taken of the damage due to lowering of tone and weakening of the bushes.

How the blight came to the tea plant in this district is not definitely known. It may have been imported into the district from Assam or have come from the jungle. Every year small quantities of seed are imported into the Darjeeling District and very probably from Dibrugarh and the surrounding tea-area where some of the best tea-seed is grown. It is possible that the blight may have been introduced with the seed or the earth in which it is usually packed. Though many spotted leaves from weeds and trees among the tea bushes and on the edge of the jungle were examined, none were found to have been caused by the same fungus (*Exobasidium vexans*) as causes blister-blight on tea. On Kharani (*Symplocos Theæfolia*) a very similar blister occurs, caused by an Exobasidium nearly related to that on tea. There are microscopic differences between the two fungi and probably they are different species. Preliminary inoculations made to see if spores from the Kharani blister would attack tea were not successful.

Methods that have been tried for keeping the disease in check resolve themselves into (1) picking off diseased material, (2) pruning, and (3) spraying with fungicides. The first and second aim at lessening the spread of the disease by removing and

destroying the material containing the spores of the parasite which cause new infection. The third aims at killing the fungus and at preventing the growth of spores that may fall on the sprayed leaves.

On Dooteriah Division ever since the blight was first seen the Manager had the blistered leaves picked off and destroyed, and it was hoped that this would have been enough to keep the disease in check. The coolies who picked the blistered leaves were not allowed to pick leaf for tea and the baskets were kept separate. The diseased leaf was burned in the factory furnace when the coolies happened to be within reach, otherwise it was buried in trenches. This saved the risk of infection while the baskets were being carried long distances through the tea or sent down the wire rope. The tea near these trenches did not become more affected by the blight than that anywhere else. In all, 620 maunds of blistered leaves were destroyed this season, yet in September the blight spread more rapidly than it could be dealt with and got beyond the available labour for treating it in this way. Thus though the blight was kept in check for a time, the result was not satisfactory.

The Manager of Pussimbing tried to check the blight by close picking. All blistered leaves, young shoots and sprouting buds were removed, whether affected with blister-blight or not, and then the coolies got round the garden once every eight to ten days. They took a bud and two leaves as usual but removed most of the third leaf as well. The idea was to take all the leaves on which the blight grows before it had time to bring its new spores to maturity. By thus continually preventing the production of spores, it was hoped that, after a time the young shoots would grow up free from blight. So far as the absence of blister-blight is concerned, the result on Pussimbing and especially on Pubong was very satisfactory. In July blight was prevalent on both gardens and severe on part of the latter, but by the middle of September there was not much blight on either.

The drawback planters urge against this method is that it takes a strong labour force to pick over a garden in the time

and in most gardens in the Darjeeling District at the present time this is said not to be available in the busy season. If a garden was in vigorous health and flushing well, it could not be overtaken in time, for even with the ordinary way of picking it is sometimes difficult to get round. Then, again, this method of close picking is practicable only in the latter part of the season after good growth has been made in the earlier part of the year, but would be dangerous after a period of unfavourable growth at the opening of the growing season. Some modification in the style of leaf-picking along the lines of this method seems, however, the most likely way of dealing with the blight in the rains, and the details will have to be worked out by a practical man on the infected gardens.

Spraying.—It was demonstrated at Tukvar in a number of small experiments that spraying with Bordeaux Mixture kills the spores and filaments of the fungus where the liquid comes in contact with them. It also does much good on young green twigs affected with blight. In the usual course of the disease when a twig becomes "blistered" the swelling extends gradually round and through the twig, and ultimately causes the part above the spot to succumb. If, however, it is sprayed before the spot has extended much, then the Bordeaux Mixture kills the fungus and the shoot recovers. This in itself is a great advantage as it saves the buds in the axils of the leaves above the affected spot to produce leaf for tea. The mixture on the leaves also prevents spores that fall on them from developing.

As spore-formation usually and infection invariably takes place on the under-surface of the leaf, this is the side that must be sprayed. That accordingly makes spraying difficult as the tea bushes are very dense. Spraying on tea gardens situated as they are on steep slopes of hill sides is an arduous task. The chief difficulties in the way are due to heavy rainfall and to the difficulty of transporting water for preparing the fungicide. During the time when blister-blight is spreading the heavy and frequent showers wash off any liquid sprayed on the leaves, and

especially on the high gardens, about the mist-zone where it is often continuously wet for days together. The fungicide does not always remain long enough on the leaves to prevent incipient blisters from maturing. It has no effect on new shoots that develop after the application, and they are just as ready to be infected and spraying must be repeated for their benefit. General spraying in the rains is impracticable, but on heavy pruning, new-extension and seed-beds, where the area is small and the blight might cause heavy loss, the labour and expense of repeated spraying would be well repaid by the saving of the plants. At Tukvar a small block of heavy pruning became well blighted in June and July. It was sprayed with Bordeaux Mixture five times, and in September looked very well, though it never became quite free from blight; a few blisters could be found here and there. The bushes were all healthy and had made good growth. The Manager was well satisfied that the result was worth the effort made. Spraying in such cases, to do good must be repeated ; once only is not enough. Buds that open after the bush has been sprayed are unprotected by the fungicide, and are liable to fresh infection and have to be covered with fungicide.

Pruning.—It is on pruning that reliance will have to be placed in combating blister-blight during the cold weather. For this one cold weather all bushes should be pruned, in the ordinary way back to the last one or two buds and the lower as well as the upper parts of the bush should receive attention. All prunings or at any rate all from affected areas should be burned or buried, and with careful cultivation following, all the fallen leaves and twigs will be turned in and rendered harmless. Prunings ought by no means to be left on the ground, nor is it sufficient, simply to turn them in during cultivation.

As it is possible and very probable that unpruned tea carries over the blight from the end of one season to the beginning of the next, it is strongly to be recommended that this cold weather no tea be left unpruned. Heavy pruned tea suffers severely, and whether the leaves are picked off or left blistered on the bush, an attack often means disaster As little as possible heavy pruning should

be done this autumn, and when it must be done, care should be exercised in selecting a plot that is not very near one that was badly affected. It is necessary that every one should adopt the measures as one neglected garden may infect a whole neighbourhood.

At the beginning of the season of 1910, a careful look-out should be kept for the first appearance of blister-blight, and whenever seen, the blistered leaves should be destroyed and the surrounding bushes should be sprayed thoroughly with Bordeaux Mixture, and after a day or two a man should be sent round to pick any leaves with fresh blisters that may have escaped treatment. Continue the treatment till the early rains come.

Recommendations for the cold weather.

It would be desirable—

To prune all bushes in the garden. The pruners should open up the bushes and remove all growth-leaf showing traces of having been blistered.

To leave no unpruned tea anywhere on the garden and to do no top-pruning (skiffing).

To do heavy pruning with caution and to restrict the area as far as possible. It should be done comparatively early to get some growth in spring before the blight may appear.

To burn prunings or to bury them in trenches under at least $1\frac{1}{2}$ foot of earth.

To have a responsible assistant go carefully over every block to see that no infected stems or leaves are left on the bushes or exposed on the ground.

To begin pruning early in the cold weather and to cultivate soon afterwards, in order that any blighted leaves or twigs on the ground may be forked in.

Every garden in the whole district should be pruned. Success in exterminating the blight depends on whole-hearted co-operation.

If blister-blight should appear in March, pick off blistered leaves at once and spray the surrounding bushes. This may be done till the early rains come.

In seed-beds, new-extension and heavy pruning, where the damage from blister-blight is considerable, be prepared to expend money on repeated application of blight-remedies because the benefit in each case would more than pay for the cost of treatment.

Indian Tea Association.

RED RUST.

A SERIOUS BLIGHT OF THE TEA PLANT.

BY

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Scientific Officer to the Indian Tea Association.

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RED RUST.

A SERIOUS BLIGHT OF THE TEA PLANT.

Early in June of the present year (1901), an urgent request was received from several planters of the Nowgong District of Assam, that I should proceed immediately to that part of the Tea Districts, there to investigate the causes of, and remedies for Red Rust, which was doing serious injury to the gardens. The Committee of the Indian Tea Association instructed me to accede to the request, and the greater part of the month of June was spent on this business. The report which follows represents the results of this investigation, together with a statement of what was previously known of the practical aspects of the disease. There are still many obscure points in connection with the blight, and it will take many months of study by a trained mycologist to fully work these out. In the meantime, however, I think that sufficient material is now in existence to enable us to devise a rational method, based on experiment and observation, for dealing with the blight.

Description of the Blight on Tea.

On walking through tea gardens in almost all tea districts of India, especially such as have not very vigorous bushes, in the months of May and June, and to a certain extent also in July and August, the eye is attracted by some of the bushes possessing a certain number of variegated leaves, partly yellow and partly green, more especially round the edges of the bush (See Coloured Plate).* This has been attributed to various causes. Some have suggested (and probably correctly in a small percentage of the cases) that it is merely a sport on the part of the bush, such as occurs occasionally with almost all plants. Others have put it down to weakness, though weakness would hardly produce such a specialised effect. Others again have attributed it to the action of 'mites,' which indeed are often present, though probably more as a consequence than as a cause of the diseased state of the bush. The stems however below these variegated leaves will, in ninety per cent. of the cases at least, be found to bear livid red or orange red spots in greater or less

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* This plate is reproduced from a painting made for me by Miss E. Scott of Salonah, to whom I here tender my sincere acknowledgments.—H. H. M.

quantity. This is Red Rust. These red spots, on closer observation, by holding the edge of the twig between the eye and the light, are seen to consist of a mass of filaments, enlarged at the tips, standing up from the bark like a tiny forest. If the circumference of such a bush as I have described be further examined, it is most probable that more or less of the twigs will be found to be dead, until at last in bad cases the bush has the appearance in June shown in Figures I and II, and the dead twigs carry either red patches as described above, or purple blotches from which most or all of the filaments have disappeared. These filaments consist of the fruiting organs of an 'alga' first described more than twenty years ago, and to which the name '*Cephaleuros mycoidea*' was applied by Karsten, the discoverer. This 'alga' is the cause of the disease from which the bushes are suffering.

When the red patches appear on a young tea shoot the following results occur :—

(1.) The green stem becomes woody almost to the tip immediately, and the green succulent part disappears all but entirely. In one such young shoot I examined, the woody part was 7¼ inches long, the green only ½ inch ; in an adjoining shoot not attacked, and apparently of about similar age, the woody part was 3 inches, the green 8 inches long. When the young stems in a bush become wooded up in this manner, Red Rust may be suspected.

(2.) The leaves in all cases become yellowish and unhealthy, and in many instances, but not in all, take on the variegated 'leprous' appearance previously described.

(3.) The stem or shoot where the patches occur becomes split in minute cracks (Figure III). Often the red patch is slightly raised and split at the edges or in the middle. The cause of this is following : Although the fruiting organs of the alga causing the disease are above the bark and visible, yet the main part or 'disc' of the alga is underneath the bark, and as it grows forces this up, the dislocation causing the minute cracks which appear in every direction.

(4.) The shoot becomes drier, ceases to grow, and finally dies.

After this has happened, or while it is in progress, the bush throws out another shoot from below the affected part. If this occurs early in the season, the new shoot will also probably be attacked, and the same cycle of changes take place. If on the other hand the new shoot is produced after the commencement of the rains, although it *may* be attacked in the same way, yet the chances are that it will not be so, and that it will be one of the flushing shoots of the bush for the remainder of the year. This apparent immunity is probably far more the result of the increased vigour of the shoots giving them the capacity of resisting the attack than of any inactivity of the disease during the rains. The smaller 'twiggy' shoots can be seen so attacked at any time till the end of the season.

As the end of the rains approaches the striking livid red blotches of Red Rust disappear, only leaving, as a rule, a very few filaments, and these often change in character, becoming very much more distinctly drumstick shaped (see Fig. IV).* But at this time (October, November and December) the blight is much less easy to be seen than earlier, and might be overlooked in many cases if special search be not made for it. New shoots are occasionally attacked, even then, in the ordinary way with the usual result.

The general result on a bush where the blight has been several years in operation without check, and which has not been heavy pruned, is to form, in the best part of the season, a narrow hard-stemmed plant with a crown of green leaves. The bushes in fact get narrower and narrower, and the small size of the plants on a garden which has long been attacked by the blight is remarkable. Many a bush described as 'hidebound' has come into this condition through the attacks of Red Rust, and I believe that a comparatively large amount of cutting down necessarily done in recent years in comparatively young tea has been caused by the unsuspected prevalence of this blight.

Leaf Form of the Blight on Tea.

There is another condition of the Rust which also occurs on the tea bush, although its immediate and direct effect does not appear to be a serious one. In almost any garden in any district one will find, on the leaves of the bushes, circular orange red spots, which, held sideways between the eye and the light, are seen to consist

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* This photograph was taken by Mr. T. H. Hall of Naganijan Seleng, to whom I here record my sincere thanks—.H. H. M.

of filaments just similar to those above described as found on the stem. When thus occurring on the leaf it may take still another form (by combining with a fungus as common as itself) and appear merely as a number of grey hoary patches. In one or other of these forms it is exceedingly common on almost any garden. Seed gardens are often, if not usually, full of it ; and to go to the other extreme, I have seen it on nurseries where the plants have only been above the ground about two months.

In this leaf form it seems, however, to be of little commercial importance. The affected leaves ultimately die, but the tree itself is not appreciably injured, and for practical purposes the direct harm it does might almost be neglected, were it not for the fact that it is at any moment liable to change into the form first described, when the damage is serious in the extreme.

Leaf Form of the Alga on Jungle Trees.

But Tea is, by no means, the only plant on whose leaves the alga occurs. The jungles of Assam and probably of all the tea districts are full of trees bearing leaves on which are found these orange red spots or grey patches. Dr. Watt, to whose description of the blight as attacking tea we owe almost all the practical information on the subject up to date, states that he has found it, among others, on the following trees: The Mango, the Lichi, the Nahor (Nagassa), the Satian, the Sum, and the Adakuri. Personally I have not seen a single Mango tree in Assam which did not bear it in one form or the other. One can hardly walk, indeed, ten yards in the jungle without finding it, although it seems to limit its field there to the trees bearing hard leaves This universality of distribution is an exceedingly important matter when one comes to consider the means for dealing with the disease, because it makes isolation almost impossible in attempting a cure—and, further, it points to immunity as a result of robustness of plant rather than of fortune in escaping infection.

Blight on the Stem of Jungle Plants.

On the other hand the serious or cortical form of the blight occurring on the stem is almost, if not entirely, unknown in the jungle. In 1895 Dr. Watt did not notice it on any plants there, though careful search was made. Shortly after that time it, or a very similar alga, was seen on the stem of the 'Sau' tree (*Albizzia stipulata*), and recently this has been further observed on several plants, of

which the Bogga Medeloa (*Tephrosia candida*) is one. Whether we have here to do with an entirely different blight, or whether the disease has spread from the tea, one cannot at present say. The point is one which demands further and long continued examination. On the 'Sau' tree, however, when it occurs on the old stems the tree seems little if at all affected for a long timé, although the branch affected ultimately dies, but if the young shoots be attacked they die out in a manner precisely similar to that in which tea is affected, and curiously enough, in both districts where I have noticed it,—Jorhat and Nowgong,—it occurs on gardens where the surrounding tea is badly affected with Red Rust.

It may be, of course, that the stem form of the alga is extending from tree to tree in all directions, and so increasing the danger under which the tea already exists ; or it may be that we have to do with quite a different organism which, for our purpose, is of little or no importance. The fact that it has now been observed on no less than six species of plant makes the former assumption perhaps the more probable, but it is a question for the decision of which the materials do not yet exist.

Extent and Distribution of the Blight.

I fear that, so far as tea is concerned, there is very little doubt that the serious stem form of the blight is extending with great rapidity. In 1895 Dr. Watt wrote : "to the best of my knowledge, it nowhere occurs until on descending the valley the latitude of Tezpur and Nowgong is reached. It is thus significant that this blight should be confined to the portion of the Assam Valley indicated. ....the restricted nature of its present distribution is certainly highly significant." A very different state of affairs now exists. I have personally found the dangerous stem form of the alga in every district in Assam save Dibrugarh and North Lakhimpur, and in the former of these it has been reported to me from at least two gardens. In Cachar its ravages are as serious as in Assam, and it is very probable that we have here one of the most serious causes of the decline and abandonment of many of the old teela gardens. I have noticed it in Sylhet, in the Western Dooars—though here only in the older Western Gardens—and in the Terai. In fact, so far as all the districts (except those in the hills, and of these I cannot speak) in India are concerned, there is little doubt that no section is absolutely free.

As to distribution in the gardens, it seems to be independent of the jungle, and appears to occur quite as frequently far away in the centre of large patches of tea as under the shade of jungle trees. Plants used for filling in vacancies are attacked on the stems by it almost everywhere, and its presence is probably one of the chief difficulties in filling up these vacancies, for it is impossible to obtain luxuriant growth in presence of this blight. It affects plants of any age, and it cannot be said that young plants are any more susceptible than older ones.

It is very difficult, if not impossible to make any estimate of the loss caused by this blight. On some of the Nowgong and some of the Cachar teela gardens it will probably not be less than 20 per cent. of the entire crop. On the whole tea area, if a few very good districts be excluded, from which it is apparently absent, I doubt whether the crop from the old tea is more than 85 to 90 per cent. of what it would otherwise be in the tea area of India (excluding the hill districts). A blight, the effect of which is anything like this, cannot be regarded in any other than the most serious light.

Causes Predisposing to Attack.

The 'alga' causing the disease with which we are dealing is very common on the leaves of jungle plants; why does it not occur in a dangerous form in all tea gardens? The fact that the distribution varies with garden, with climate, with attention, with manuring, renders it at first sight most probable that there are some conditions present in one case and not in another which lead to the excessive development of the blight. If these conditions can be determined, it is evident that we shall be on the track of a far more certain method of dealing with the blight than any system of direct attack would be. Dr. Watt said in 1897 with regard to quite another blight, but the idea is quite as appropriate in the present instance, "from my stand-point, if a blight or pest recurs time after time on the same plot of tea, or similar plots of tea, it is time to look further afield than to a palliative treatment. . . . . There is something materially wrong either in the soil, in the drainage, in the ventilation, in the general health of the stock, or in the class of stock itself on such plots of land, that imperatively dictates prevention as more effectual and more economical than cure. We must seek for the cause of the predisposition to pests and deal with that." With this idea, I have devoted a great part of the time recently spent in Assam to an effort

to try and ascertain the unhealthy conditions under which the blight becomes most serious, and to a comparison of these with those prevailing in near lying gardens not badly affected.

As a result, I am able to confidently state that it is in defective soil conditions that the cause of the blight is really and primarily to be found. As occurring on the worst gardens visited, the soil may be described as a rather heavy loam, dark brown when wet—greyish when dry, containing much more clay than is usually found in the best tea soil. The surface is fairly friable down to a depth of 10 inches to one foot,—just so far, in fact, as the cultivation extends. Immediately below this is a hard impermeable clayey subsoil forming what is usually known in agriculture as a 'pan.' Below this again is a slightly softer clay interspersed with the fragments of the dark red laterite rock usual in the locality. The gardens have none but surface drains. The results of these conditions are—

(1) Owing to the 'pan' immediately below the cultivated depth and to the absence of drains, the top layer is nearly always (except in the rains) too dry and the lower layer too wet. As an example of this condition of things I may say that a determination of moisture made in this subsoil at 3 feet deep in December last, when the surface was dry and powdery, gave 20lbs. water to the cubic foot, the total amount which it could contain when saturated being 27lbs.* This water was unavailable because of the more or less impermeable 'pan,' and even were it available roots could not penetrate a soil so near saturation as the above figures show.

(2) Plants growing on such a soil are almost entirely dependent on the surface layer for moisture and for food—and their root development is almost entirely a surface one. This was found strikingly to be the case when bushes were dug up for this purpose. Figs. V and VI, from actual photographs, show what really was the case. The root system in fact consists in a spreading shallow mass of roots such as would be quite admissible, if sufficiently manured, in the English climate where the soil is always moist, but which is entirely out of place in a situation experiencing long droughts such as prevail in Nowgong. That the failure of the roots to descend was caused by the impervious nature of the ground was rendered certain by an examination of the roots themselves. In one case

* I am indebted to a report by Mr. Ede of Silchar for these figures.

a root was observed proceeding directly downward, but on reaching the layer of soil in question, it suddenly was bent back on itself and came up again. Another root penetrated the layer for a few inches, becoming very rapidly thinner during the process, and then split into two, both of which went no further down, but only horizontally for a short distance. In these ordinary conditions the extreme depth to which the roots penetrated was only from 18 inches to 2 feet in the soil,—these numbers being obtained by actual measure.

These conditions are of course most unhealthy, but it remained to compare the amount of Red Rust here with that in gardens similarly situated, except that descending roots were produced. This was done on an adjoining place. The surface soil appeared to be similar, but the subsoil was lighter in texture and the land was drained. The bushes were of about the same age, but the section has been recently top-dressed. Here Red Rust was certainly found on a good number of bushes, but in no place did it amount to such an actually serious blight as on the gardens previously mentioned. This indeed I found to be generally the case in Nowgong,—where the subsoil was fairly light and the land was drained, the blight, though present, did not appear to be very serious,—without drainage and with a hard subsoil it was extremely so.

Another striking example of the effect of soil conditions is furnished by the comparison of the effect of heavy pruning in different places. On the first mentioned garden a portion was collar-pruned in 1899-1900, and another in 1900-1901, in the hopes of getting rid of the unhealthiness in the bushes. I found Red Rust already again in these plots, doing serious damage. I then went to a garden in Tezpore which contained a large plot seriously affected with Red Rust a year ago. The Manager, on my recommendation, cut back part of the area then (in July 1900), and the remainder in the winter of 1900-1901. Although a great part of these plots was carefully examined, I utterly failed to find any Red Rust except on a few snags left by mistake in the cutting back, and on a very few weakly bushes. But here the land was drained to 3 feet and the roots penetrated by actual measure at least to 4 feet deep, and their development was of an entirely different character. The treatment, if cutting hard is a cure, was nothing like so radical as in the former case, but the Red Rust had been practically eradicated nevertheless.

Methods of Preventing Attack.

The conclusion is obvious. While the blight is of almost universal distribution, it will only enter as a serious disease where favourable conditions arise causing lack of vigour in the tea, the most notable being the lack of extended and deep root development in the soil, which results in rapid exhaustion of the shallow layer from which the food-supply is drawn, and in great susceptibility to drought. Is this a defect, however, which can be removed? In many cases I think it is, and that the removal of this defect is the proper first step to the eradication of the blight.

The primary means of increasing deep root development is by deep draining. The worst gardens for Red Rust that I have seen have been undrained, badly drained, or drained only recently. The only garden I know where the blight has been regularly fought and is in a fair way to be conquered is one where drainage has formed one of the main lines of attack. The effect of a correct system of drainage is to remove excess of standing soil water, and in many cases it may be said that the depth of possible root development is determined by the depth of the drains. It has been argued that owing to the short rainfall in Nowgong, drainage can hardly be needed there. As a matter of fact, there is no district in Assam where it is more needed, for there the soil is stiffer and less permeable than is usual in the valley, and consequently a hard pan is apt to form at the depth of the annual deep hoeing, below which is water which only very gradually gets away. (*Vide* example cited, page 7.) Part of the land from which this example was taken was drained to 3′ 6″ in December last, and the effect on the roots is already visible. On exposing the roots of several bushes in June 1901, they already were found to penetrate to two feet six inches to three feet deep, as against an extreme of two feet on the undrained portion of the same plot of tea. It is then evident that the drained plot will in the future be much more independent of drought than the undrained, inasmuch as it has a larger extent of soil to tap for water and for food—an extent however which never contains enough water to prevent its root growth. Probably one bush will be able to utilise 60 to 70 cubic feet of soil, where its previous range only extended to 25 cubic feet.

But drainage having been carried out, the greatest effort should be made to force the plant to utilise the new soil put at its disposal

by very deep cultivation, or (what is probably in many cases as useful) ordinary deep cultivation and trenching 2 feet deep between alternate rows each year; by breaking up the 'pan' by growing trees among the tea; by green manuring with a deep rooted leguminous crop. 'Sau' trees would naturally be recommended for growing in the tea area, and they to a certain extent fulfil the object in view, but on such soil as I have in mind they hardly seem to be deeply enough rooted to be an ideal for the purpose. Though the 'Grevillea' has no manurial action like the 'Sau,' yet it might be better for this purpose owing to its deep tap root. This is however distinctly a matter for experiment. For green manuring 'muttee kalai' (*Phaseolus aconitifolius*) is naturally the first plant thought of, but its roots do not seem to be quite the best for this purpose, as they do not appear, where I have examined them, to be more than ten inches deep. It likewise needs experiment to decide the best leguminous crop for the purpose, but in the meantime 'muttee kalai' should be used.

There are cases where drainage will not, however, suffice. The upper layers have become so exhausted and the lower layers are so poor that the bush has not the food necessary to give it vigour even if its root range is extended. In such cases manure in some form is essential. Manure alone, even, is of great value. On one plot, as poor, weak, and rusty as any, in one of the gardens visited, a new set of coolie lines were placed eighteen months ago. Now, the part round these lines, though it contains a great deal of rust, seems to be resisting it with much greater vigour than elsewhere, and it is here a rarity to see a bush of which half the foliage is killed—a common sight in the remainder of the section. Further, those gardens in Nowgong, with soil such as I have described as favourable to Red Rust, which have suffered least are those on which top-dressing and manuring has been most systematically carried out. Such manures should be used as will give vigour to the bushes as, for example, top-dressing bheel soil material if good; cattle manure if available; oil cake if cattle manure cannot be obtained; or green manuring with 'muttee kalai;'—all these being manures which increase the vigour of the tea bush and do not only increase the yield.

Methods of removing the blight.

While I believe that the methods above indicated will suffice to prevent an attack of Red Rust or to prevent it, at any rate, from

assuming serious proportions, yet, alone, they will not be sufficient to eradicate the blight. In such a case it will be equally necessary to remove the blight itself, and the most drastic methods have often been recommended for this purpose, such as collar-pruning and burning all the prunings, or even burning the bushes *in situ* on the plots. The great question in a case like this is whether, if these drastic measures are adopted, we have any guarantee that the disease is really eradicated, and whether milder methods will not bring about the same result. In my own investigations I have tried to keep these points in view.

From my recent experience in Nowgong it appears that collar-pruning and burning all prunings does not result in producing healthy plants in all cases. Both in bushes collar-pruned in 1899-1900 and in 1900-1901, Red Rust was found doing serious mischief on the young shoots—many of these being either dying or dead. If, therefore, collar-pruning is not a certain means of eradicating the blight, it remains to be seen whether any other method will get rid of as much blight as this treatment. In connection with this the interesting observation was made that bushes which had been hard pruned and the remaining stems treated with the Lime and Sulphur mixture suggested in my Circular No. 75 of December 1900 on the eradication of Thread Blight, showed in June 1901 no trace either of this or of Red Rust, and the shoots were more vigorous than from collar-pruned bushes. While one cannot think that these bushes would really be any more immune than those collar-pruned, yet the result certainly suggests that it may not be necessary to cut down to the ground, but that less drastic treatment may suffice, provided it is combined with a dressing of the stems left after pruning.

Accordingly a large number of bushes were sprayed with 'Bordeaux Mixture', 'Sulphide of Potassium' (Liver of Sulphur), and the Lime and Sulphur mixture used for Thread Blight. In the last case the result has however so far been inconclusive, and further it is not a convenient material to spray. The spraying was done from below so that the stems were all wetted, as far as possible the leaves not being touched—and the bushes were examined at a later date. The most thorough test was made with Bordeaux Mixture. Here within 20 hours a large proportion of the visible part of the blight had disappeared. This had been previously

noticed by Mr. W. J. Fleet in 1895,* and I am pleased to be able to confirm his observations. Further than this, a microscopic examination of those parts of the blight still remaining on the bush showed the contents of the heads of the filaments to be shrunken, and the spores found there to exhibit no motion as is the case in the living alga. The visible structures are therefore dead. The mixture was then left on the bushes for ten days and the branches again examined, and what few filaments of the alga remained had, by this time, quite changed color becoming almost white, and were evidently quite destroyed.

The effect with Sulphide of Potassium appeared to be the same, but was not so carefully gone into. It is however a solution more easily made, and might have advantages over the Bordeaux Mixture.

These were experiments only. However effective such mixtures might be, it is evident that we cannot apply them in the middle of the season as at present, and that, if applied at all, this must be done after pruning in the cold weather. A doubt has been raised as to whether the deep-seated portion of the alga under and in the bark is killed, but as the Bordeaux Mixture sticks on the stem for a long time, and thus would prevent any extension of the growth of the organism by depriving it of the parts which supply it with air, it is probable that it is of little importance whether it is immediately killed or not, as it will ultimately die in any case. The evidence is nevertheless strongly in favour of the idea that the whole of the alga is immediately killed. The material of which it is composed is very absorbent, and hence the fungicide liquid would immediately diffuse throughout the whole structure.

A further observation seems to show the extent to which such spraying might be profitable. If rust attacks a first year shoot, that shoot inevitably dies. A second year's shoot in my experience likewise always succumbs. But on older wood, this is not universally the case, though very often the attack is fatal even on these stems. The reason why this older wood is not always killed is shown by careful microscopic examination. If first or second year's affected shoots be examined, the alga is found to have perforated right into the interior of the shoot through the protective layer of corky tissue.

* See paragraph 867 of Dr. Watt's 'Pests and Blight of the Tea Plant.'

In older wood this is, however, not always the case, and if the stem is vigorous, it may be able to throw off the disease before such penetration does take place. Hence the amount of pruning absolutely necessary in such cases seems to be indicated. On a plot of land badly affected with the blight, it would appear therefore sufficient to prune out the last two years' wood, removing all the small twiggy shoots which invariably contain Rust, and spray the remainder of the bush with Bordeaux Mixture or Sulphide of Potassium, taking care that every part is reached by the spray.

The amount of liquid required to spray the bushes at present, when all the leaves and small branches were on, amounted in a test made on the garden in June to about 175 gallons per acre. Under the conditions I suggest above not more than 100 gallons per acre could be required, costing for Sulphate of Copper in the Bordeaux Mixture about two rupees. With Sulphide of Potassium the same amount of liquid might be used, costing for material likewise about two rupees. In all these cases it is of course perfectly understood as absolutely essential that the whole of the prunings should be immediately burned, and the ashes returned to the soil.

As far as machines for spraying are concerned there are several on the market which would not cost very much, and would, I think, be perfectly effective, made by either English, American or French firms. Details of these I shall be happy to supply.

Safeguards against fresh attacks.

But though apparently satisfactory so far, this is not enough. Inasmuch as the whole jungle is crammed full of the blight, in the leaf form above described, and that hence the tea is always in danger of a fresh attack, it becomes necessary to watch the new shoots on the bushes treated as above. It would seem possible to have a few boys trained to recognise the red patches on the stems, and to have these boys going round and round the plots treated as above, from April to June, and cut out every trace of blight which appears on the young shoots. I have seen this cutting carried out, but as it was always done by untrained people, an enormous amount of unnecessary and hurtful destruction of wood took place. If the trained boys were able, in addition, to put a patch of Bordeaux Mixture below the point at which the plant was cut, assurance would, I think, be made doubly sure.

In addition to these methods it seems that one ought to take precautions against the spread of the blight from sources actually in the garden. I fully agree with Dr. Watt's suggestion that seedlings used for filling vacancies should always, before being planted out, be dipped in Bordeaux Mixture or Sulphide of Potassium, the former for preference. He recommends it in the case of blighted seedlings; I would do so in every case. The trouble and expense would be small, but it is a safeguard one cannot afford to neglect, both for the sake of the seedling and for that of the garden round it.

As a further precaution it would be wise to spray the 'Sau' trees in the gardens. The stems are so commonly covered with what is at any rate a very similar blight, that if this is not done it becomes a question whether their danger is not greater than their value. But I see no great difficulty in checkmating the disease in the way I have indicated, especially as they are not usually planted less than 40 feet apart, and hence could not amount to more than 25 to 30 per acre. Previous to spraying it would do no harm if they were pruned considerably, only remembering that the 'Sau' tree always dies back to a joint, and cutting accordingly.

Conclusions.

In conclusion, therefore, let me sum up the results which appear to bear on the practical treatment of the blight.

(1) Red Rust is now one of the most widely extended of tea blights, and though doing most damage in the Nowgong and Cachar Districts, it can be seen almost everywhere. Even where not noticed elsewhere, it can almost always be seen on the stems of plants used for filling up vacancies in old tea. A form, not itself of serious consequence, occurs almost everywhere on the leaves of the tea in the gardens.

(2) The blight abounds in the jungles on the leaves of many trees, and apparently on the stems of a few, but its entrance into the tea garden as a serious blight is caused largely by defective soil conditions leading to the formation of roots near the surface only, resulting in susceptibility to drought, and to exhaustion of the limited soil available for feeding purposes. These conditions which lead to the blight becoming a serious pest can largely be counteracted by—

(*a*) drainage,—deep drains not less than 3 feet deep are necessary,

(*b*) deep cultivation leading to the forcing of the roots into a lower layer; or trenching between the rows still deeper which has the same effect,

(*c*) growing deep-rooted trees among the tea,

(*d*) manuring by top-dressing with bheel soil, by cattle manure, by oil cake, or by green crops.

(3) The blight itself can be dealt with by cutting out the last two years' wood at least at pruning time, taking special pains to remove the small twiggy shoots in the bush, and spraying the bush thus pruned with Bordeaux Mixture, or Sulphide of Potassium solution. In fact it would probably be advisable to thus spray all cut-back tea in affected districts. From April to June trained people should be employed to cut out every trace of a new infection in these parts.

(4) The future should be safeguarded—

(*a*) by dipping all seedlings intended for transplanting into old tea in Bordeaux Mixture before planting out.

(*b*) by spraying or painting the 'Sau' trees in the garden at pruning time with the same mixture if possible.

Treated by these methods it appears that the blight may be kept in hand. There will always be, inevitably, a trace of it in many gardens, but by the application of the means indicated, there seems a probability that the blight will not remain a serious one, while otherwise it will gradually, though with exceeding slowness, but yet inevitably, ruin many fine properties in all the tea districts of India.

APPENDIX—

Preparation of Bordeaux Mixture.

Dissolve 3 pounds of 'Agricultural Sulphate of Copper' in 23 gallons of water in a wooden tub (not in a metal vessel). In another vessel slake 3 pounds of quick lime, if possible freshly burnt, adding 2 gallons of water gradually. This lime should form a turbid smooth liquid without any lumps. Finally add gradually the

lime liquid to the Sulphate of Copper solution, stirring meanwhile. When thoroughly mixed the liquid is ready for use, but must be kept stirred up.

Preparation of Sulphide of Potassium Solution.

Dissolve 1 pound of 'Liver of Sulphur' in 25 gallons of water in a wooden tub, and apply as with the Bordeaux Mixture. 'Liver of Sulphur' must be kept in a closed bottle or tin.

H. H. MANN.

600—2-8-1901.

FIG. I.—Bush badly diseased with "Red Rust" in June, 1901.

FIG. II.—Bush badly diseased with "Red Rust" in June, 1901.

FIG. III.—Stem affected with "Red Rust" showing numerous small cracks produced.

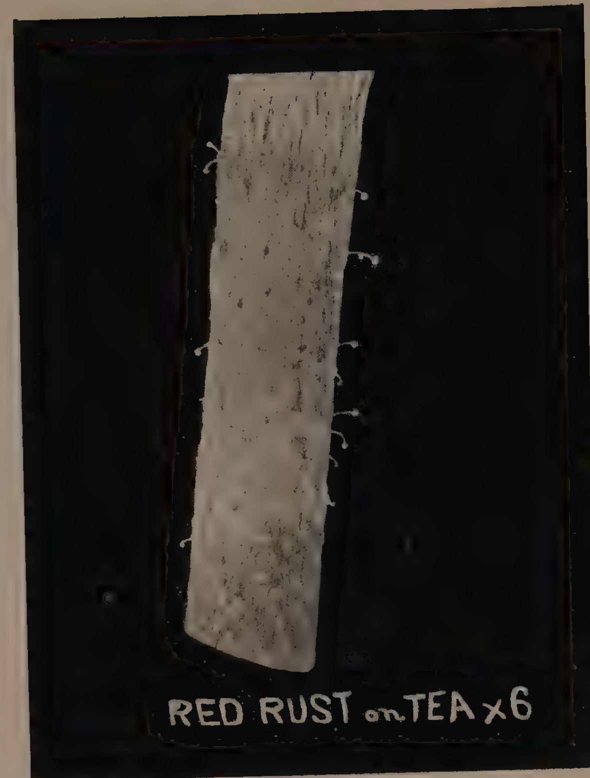

FIG. IV.—Twig showing "Red Rust" as seen in autumn (October, 1900).

FIG. V.—Bush (showing roots) on plot badly affected with "Red Rust."

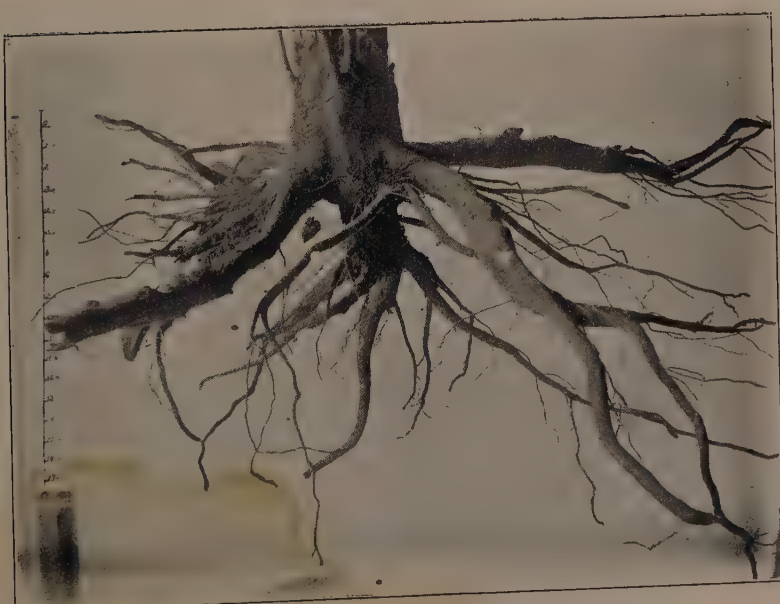

FIG. VI.—Roots of Bush on plot badly affected with "Red Rust."

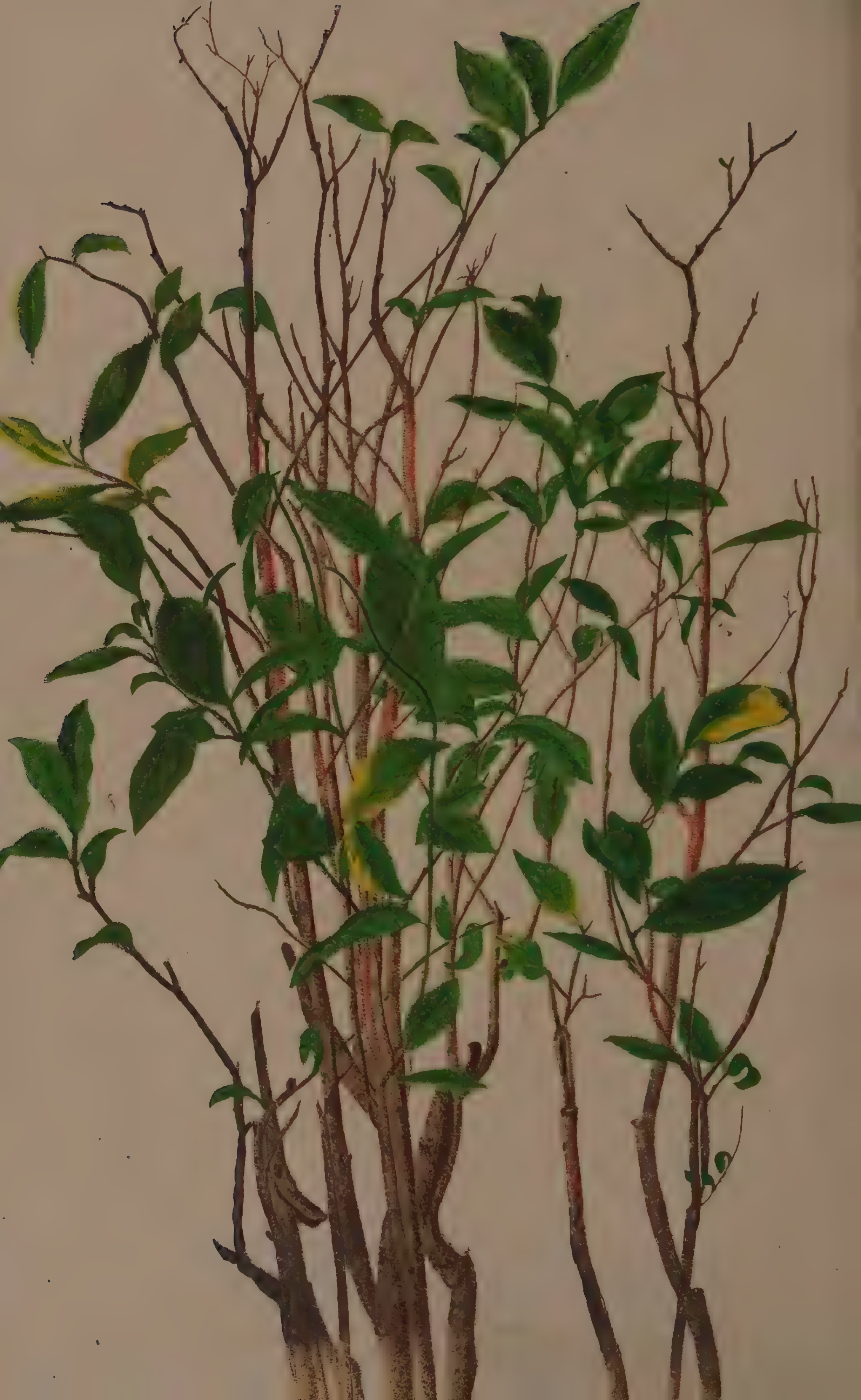

PLATE I.

Variegation of leaves produced by Red Rust attack.

904—No. 4.

Indian Tea Association.

RED RUST:

A SERIOUS BLIGHT OF THE TEA PLANT.

(SECOND EDITION)

BY

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PREFATORY NOTE.

THREE years ago one of the present writers conducted a preliminary enquiry into the nature of, and the means of combating, the tea blight known as *Red Rust*. The results of the enquiry were published in a report of which the following paper may be said to be in some respects a revised edition. In other respects it is much more than this, for certain new discoveries, which have been made since 1901 and particularly during the current season, have necessitated a complete recasting of the treatment, although they have in the main confirmed the conclusions previously arrived at. To a great extent, therefore, the report now presented is a new account of the blight, with which it endeavours to deal from a practical point of view. It also includes, the writers believe, almost everything that is so far known concerning *Red Rust*, and that is at the same time likely to interest planters.

H. H. MANN.
C. M. HUTCHINSON.

15th December 1904.

RED RUST.

A SERIOUS BLIGHT OF THE TEA PLANT.

Among all the diseases which have attacked the tea plant in recent years in India, there is none which is more dangerous nor more insidious than that which has obtained in the Indian tea districts, the popular name of '*Red Rust.*' Its definite recognition as a tea-blight only dates back at most to 1890, when it was detected on twigs sent from Nowgong (Assam) to the Botanical Gardens, Calcutta, though for long before that time the affection had been noticed without recognition of its cause. In the tea districts it was then regarded as little more than a curiosity in spite of the fact that the authorities in Calcutta expressed great alarm about it.

Dr. Watt's tour in Assam in 1895 showed that the blight was far more widespread than had been previously thought, and his report, issued in 1898, indicated that it was likely to become a serious danger to the tea industry. Only since 1900, however, has the extreme importance of this blight been recognised. Now it has been shown to be present,—and present to a serious extent,—in every plains district of North-East India. Year by year its ravages have become more and more obvious, and it has taken its place as the most serious of the "blights" (as distinguished from the animal '*pests*') which attack the plant. It has, therefore, become of greater and greater importance to get to know the life-history of the alga which causes the disease, and also to conduct experiments with a view of discovering means of dealing with it. Though, even yet, we have not yet been able to completely clear up all the points in connection with the disease, we are now in a position to state, a good deal more definitely than hitherto, the nature of the blight, the methods by which it spreads, the causes of its seriousness in particular places, and the means which are likely to be of use, not in eradicating the disease (for that is not likely ever to be accomplished) but in bringing it under control.

Description of the Blight on Tea.

In walking through tea gardens in almost all the tea districts of North-East India, especially such as have not very vigorous bushes, in the months of May and June, and to a less extent also in July

and August, the eye is attracted by some of the bushes possessing a certain number of variegated leaves,—partly yellow and partly green,—more especially round the edges of the bush. (See Plate No. I). This has been in the past attributed to various causes. Some have suggested (and probably correctly in a small percentage of the cases) that it is merely a sport on the part of the bush such as occurs occasionally with almost all plants. Others have put it down to weakness, though weakness would hardly itself produce such a specialised effect. Others again have attributed it to the action of mites, which indeed are often present, though probably more as a consequence than a cause of the diseased state of the bushes. On closer observation, however, the stem below these variegated leaves will in ninety per cent. of cases at least, be found, in May and June, to bear livid red or orange-red spots in greater or less quantity. If these orange-red spots be held sideways between the eye and the light, they will be noticed to consist of a multitude of filaments rising up from the bark like a tiny forest. This is the final or '*seeding*' stage of the blight termed, 'Red Rust.' Though the variegation of the leaves is the most obvious mark of an affected bush, yet the blight is by no means confined to shoots bearing such leaves, and if the circumference of such a bush as we have described be further examined it is most probable that more or less of the twigs will be forced to be dead, until at last, in bad cases, the bush has the appearance in June shown in Plate II (Figs. 1 and 2), and the dead twigs either carry red patches, as described above, or purple blotches from which most or all of the filaments have disappeared. These filaments consist of the fruiting organs of an 'alga' first described more than twenty-five years ago, and to which the name '*Cephaleuros mycoidea*' was applied by Karsten, the discoverer. This alga is the cause of the disease from which the bushes are suffering, and it is now our duty to describe the nature and life history of the cause of the blighting of the bushes.

LEAF FORM OF THE BLIGHT.

When first discovered the alga in question was of a totally separate character, and had habits quite different from those just given for it when present as a tea blight. In the form originally noticed it can be found in almost any piece of tea or any stretch of forest jungle in North-East India. The alga, as then known, was entirely confined to the leaves of plants, and there formed circular orange-red spots (as shown in Plate III) which, held sideways be-

FIG. 1.—Appearance in June of bush badly blighted with Red Rust.

FIG. 2.—Appearance in June of bush badly blighted with Red Rust.

tween the eye and the light, are seen to consist of filaments similar to those found in the patches on the stem of our blighted tea. When thus occurring on the leaf it may take still another form (by combining with a fungus as common as itself) and appear merely as a hoary grey patch, also shown in Plate III. In one or other of these conditions it is exceedingly common on almost any tea garden or any piece of jungle. We have never seen a Mango tree free from it. It occurs, among other trees, on the leaves of the Lichi, the Nahor (Nagassa), the Satian, the Sum, and the Adakuri. One can hardly walk indeed ten yards in the jungle without finding it, and although it seems to limit its field to the trees whose leaves have a hard surface, yet it occurs on the leaves of nearly all such trees. Even tea seed gardens are commonly full of it and it occurs on the husks of the cases of tea seeds themselves. To go to the other extreme, we have seen it on the leaves in tea nurseries where the plants have only been above the ground about two or three months.

This universality of distribution is an exceedingly important matter when one comes to consider the means for dealing with the disease, because it makes an attempt at isolation of the plants or plots affected almost an impossibility in attempting a cure, and, further, it points to the immunity of any plant being rather the result of that plant's robustness than of its fortune in escaping infection.

But were the form thus occurring on the leaves of tea, among other plants, the only one, the blight would be of little, if any, practical importance. The affected leaves ultimately die, but the disease grows very slowly, and the number of them which it could kill in a season would be very small. The tree or bush is not appreciably injured, and from a commercial point of view, the injury it produces might almost be neglected, were it not for the fact that it is at any moment liable to change into the dangerous form occurring on the stem, as first described above, when the damage is serious in the extreme.

Blight on the Stem of Jungle Plants.

The stem form is not nearly so common on plants found everywhere in the jungle, as that on the leaf, just described. To such an extent is it rare, in fact, that it was not noticed to occur on any plant save tea, in this form, by Dr. Watt in 1895. Shortly after that time it was seen on the stem of the '*sau*' tree (*Albizzia stipulata*), and now it has been noticed on quite a number of different plants. Of these the '*Bogga medeloa*,' (*Tephrosia candida*) which has been used as a manurial crop on some gardens, is one.

The importance of the fact that the blight occurs on the stem of the '*sau*' tree will be easily seen. It exists there on the old and on the young stems without distinction. In the former case the tree seems little, if at all, affected for a long time, although the branch attacked ultimately dies, but in the latter, the young shoots die out in a manner precisely similar to that in which tea is affected. The argument has often been used to us, that this occurrence on the '*sau*' tree is in itself a condemnation of the use of these trees in tea estates. We will deal with this point in another part of this report, but here it may be said that the attack of the '*sau*' trees seems rarely to be the cause of the blight on the tea, and that the process is rather in the other direction, from the tea to the trees, the latter being less susceptible than the former. It is, in fact, a certainty that the '*sau*' trees seem rarely, if ever, to be affected except in otherwise badly blighted gardens.

Extent and Distribution of the Blight.

Though the stem form of the alga cannot be considered common on jungle trees, it occurs frequently enough, in this position at present, on the tea bush, and we are afraid that there is now no doubt whatever that the blight is extending its ravages with great rapidity.

In 1895 Dr. Watt could write "to the best of my knowledge, it nowhere occurs until on descending the valley the latitude of Tezpur and Nowgong is reached. It is thus significant that this blight should be confined to the portion of the Assam Valley indicated .... the restricted nature of the present distribution is certainly highly significant."* A very different state of affairs now exists. We have ourselves found the dangerous stem form of the 'alga' in every district of Assam, without exception. In Cachar its ravages are as serious as in Assam, and it is very probable that we have here one of the most serious causes of the decline and abandonment of many of the old teela gardens. It is the first blight which appears seriously when the bheels of that district lose their original fertility and begin to decline in luxuriance. It has been noticed in Sylhet, in the Duars, and in the Terai. In fact, so far as all the districts in India, except the higher parts of the hill gardens, are concerned, there is little doubt that no section is absolutely free. We would indeed go further than

* It is probable that the disease was more widely spread, even in 1895, than was thought by Dr. Watt, and that it was not observed by him owing to his visit not coinciding, in other districts, with the fruiting season of the alga.

To face Page 5.

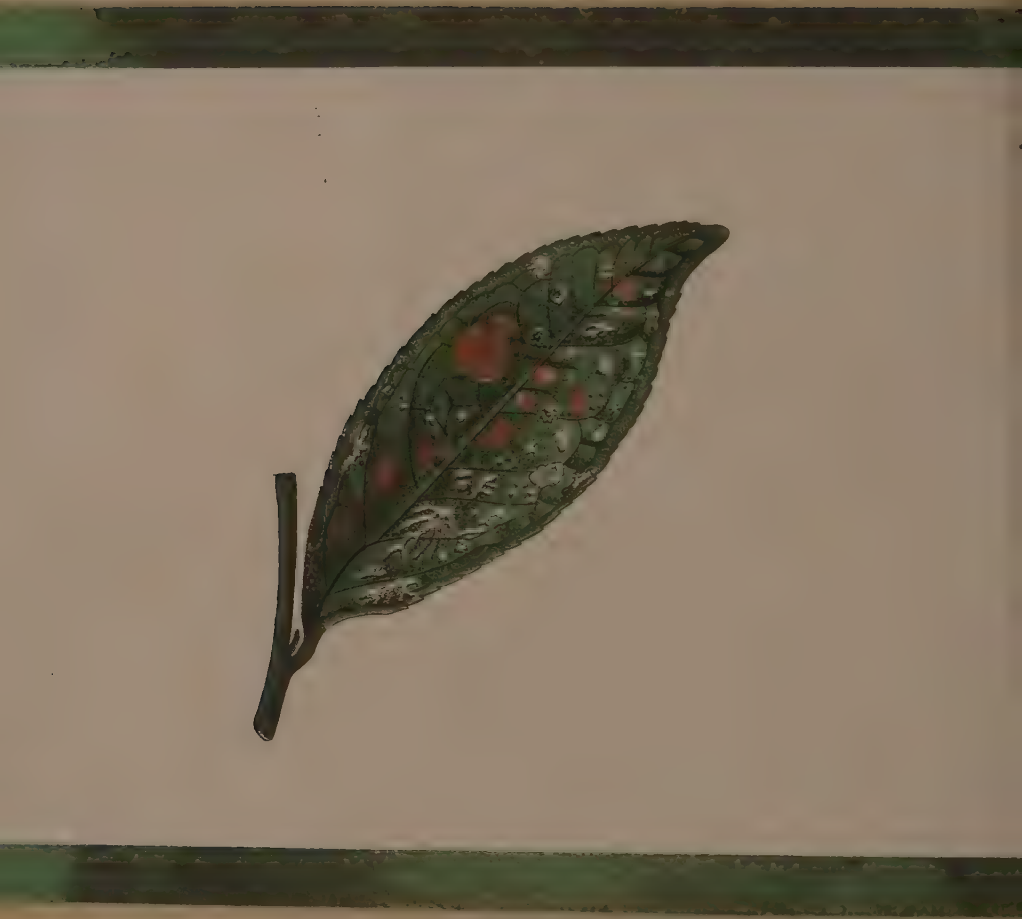


PLATE III.

Appearance of Red Rust patches on tea leaves as (1) red fruiting alga. (2) lichen.

this, and state as our conviction, based on the examination of a very large number of cases, that the blight occurs on *every* garden and is only kept under control owing to the great luxuriance of the bushes. Let these bushes get non-luxuriant from any cause whatever, and the blight, already present in traces, will usually appear to an extent which causes as much surprise as alarm.

As to distribution in the gardens, it seems to be independent of the jungle, and appears to occur quite as frequently far away in the centre of large patches of tea as under the shade of jungle trees. Plants used for filling in vacancies are attacked on the stems by it almost everywhere, and its presence is probably one of the chief difficulties in filling up these vacancies, for it is impossible to obtain luxuriant growth in presence of this blight. It affects plants of any age, and it cannot be said that young plants are any more susceptible than older ones.

It is difficult, if not impossible, to make any estimate of the loss caused by this blight. On some of the Nowgong and some of the Cachar teela gardens, it will probably not be less than 20 per cent. of the entire crop. On the whole tea area, if a few good districts be excluded, we doubt whether the crop from old tea is more than 85 to 90 per cent. of what it would otherwise be in the tea area of India. A blight, the effect of which is anything like this, cannot be regarded in any other than the most serious light.

Life-History of the Alga.

It will now be necessary to give the results of a close study of the life-history of the 'alga' as it attacks tea, first in the form occurring on the leaf, which is of little direct importance, and then in the condition occurring on the stem, when it becomes of great seriousness.

At almost any time of the year, but especially about the middle of June, and on from this date for about two months or more in most districts, if some of the old leaves of the tea plants be examined with a microscope, exceedingly small green patches, of nearly the same tint as the leaves themselves, will be noticed. If one of these patches be kept under observation for some time its area is seen to get larger and larger, but to be entirely on the surface of the tea leaf, from which it can, in fact, be entirely removed by a sharp knife with but little injury to the leaf. After a few weeks one of the two things may happen to it. Either it goes on growing for a time which varies with the season, and finally forms the orange-red fruiting organs which make it so obvious, or it combines with a black

fungus, also very common on the leaves and forms grey lichen patches, on the edges of which one can nevertheless sometimes see the orange-red fruiting organs. Both these conditions are shown in Plate III. Exactly the time it grows before fruiting and thus becoming orange in colour is doubtful and probably variable. It is certain, however, that if for any reason the leaf begins to wither, or dry up, or even get less vigorous, it forms fruits at once. This is even the case when the alga is only a few weeks old. Thus, it will easily be seen that these apparently harmless patches of blight on the leaf, with the possibility of seeding, and so spreading to other leaves and stems at frequent intervals, may be, and doubtless are, the intermediaries for distributing the blight quickly over gardens. As the importance, from this aspect, of the leaf form is hardly recognised among planters, we would rather insist on it as a possible and even probable method of widespread infection. As we have said before, however, the direct damage done by the form just described is negligible.

The life-story of the alga on the stem is quite different. It starts, however, quite similarly. The infection takes place most commonly in June, July, or August. At this time the new wood on the tea bushes has a very rough surface. The original brown skin on the newly grown shoot is being split by the growth of the stem in every direction forming sheltered cavities at all parts of the shoots. (See Plate IV). The spores (*i.e.*, seeds) of the *alga* are blown about by the wind, and light in such sheltered corners, and, finding enough moisture for germination, these begin to grow. About the end of July, the newly growing, very minute, green patches can be found in a very young condition on such stems in large numbers. But at this stage the growth begins to show very great differences from what occurs on the hard surface of the leaf. In the latter case, it forms purely a surface growth,—on the woody stem it rapidly commences to penetrate the bark and there continue its growth underneath the surface. As a result the bark begins to split, usually longitudinally, with minute cracks, and thin layers fall off. When this has happened once, the penetration of the remaining layers of the bark is resumed and soon a second thin layer is lost. So that, little by little, the bark layer becomes thinner and thinner, until finally the cells of the alga penetrate beneath the bark altogether into the living layers of the stem (known as the cambium layer), and there feeds on the sap rising from below for the use of the shoot.

The natural result of this tapping of the food supplies of the shoot is that the latter becomes less vigorous, ceases to form new

FIG. 1.—Microscopic appearance of Red Rust on tea stem, in the fruiting stage.

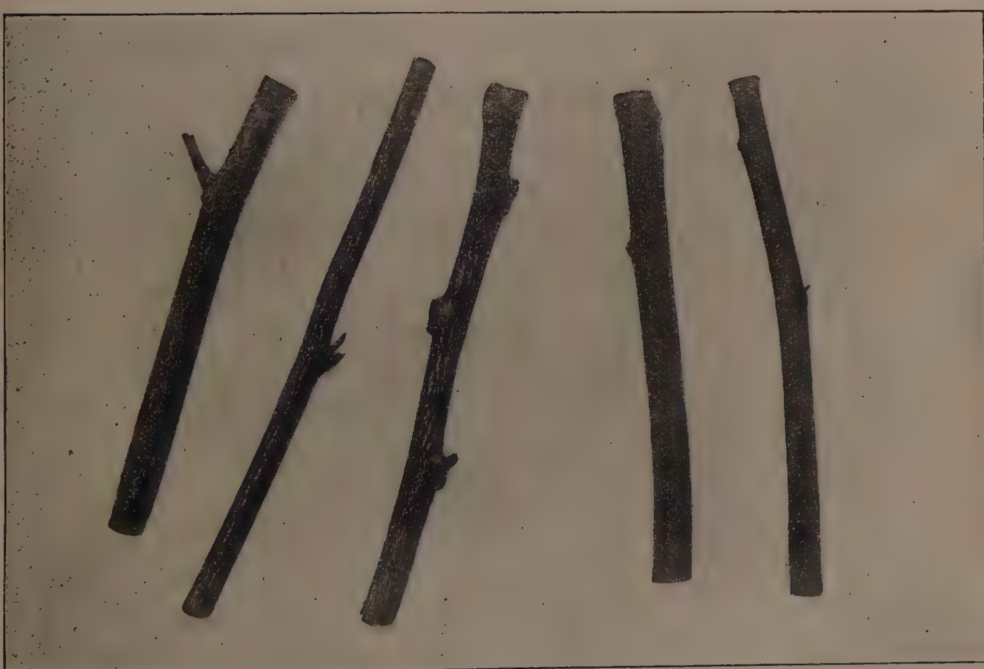


FIG. 2.—Young tea stems (to the left) and older tea stems (to the right), showing the much rougher surface of the former.

leaves, and rapidly goes *banjhi.* The final stage is reached when the sap supply is not sufficient for both the shoot and the 'alga.' Then the leaves on the ill-nourished shoot became first yellow and sickly, and finally variegated, and the alga forms its orange-red fruiting organs which produce spores carried far and wide by the wind to infect other plants. Shortly after reaching this stage the shoot dies, while the 'alga' often lives on for some time after the shoot is dead until the completion of the fruiting period, when it dies also.

As we have said, the infection usually seems to take place on new shoots in June, July, or August. The growth of the alga and the destruction of the bark takes place during the following months including the pruning season. The operation of pruning cuts off by far the greater proportion of the growing alga, which is then burnt or buried as the case may be. In either case it perishes. Enough, however, is left on the pruned shoot to go on growing, and many of the worst affected shoots, being thin and round the edge of the bush, are not, in many districts, pruned at all. The final stage occurs principally during the months of April, May and June, when on a badly affected property the variegated leaves and orange-red stems seem to develop suddenly from end to end of the place. Little by little the leaves fall off the affected shoots, which then die, and the appearance of many of the bushes in a bad attack is well shown in Figs. 1 and 2 (Plate II), or (for part of an unpruned bush) in Plate V.

New growth then takes place from the lower part of the bush (well seen in Fig. 2. Plate II), and the injury, in an otherwise vigorous bush is soon covered over. The damage has, however, been done,—two months, more or less, has been largely lost from the flushing season, the yield of leaf has been largely curtailed, and the bushes are weaker than they were before the attack. The result of repeated doses of Red Rust can only be a small non-luxuriant, non-yielding bush, and ultimately a dead one.

Resistance of Plant to the Blight.

But the cycle of changes we have described does not always take place. We have said that Red Rust occurs in small amount, on probably every garden in the plains of North-East India. Why, then, are not all attacked to the extent here indicated, and how is it that tea-planting is still possible in presence of such a powerful enemy? The answer is that, when the alga begins to grow on the stem the plant immediately prepares to resist the attack. If the

plant is flourishing, vigorous, and luxuriant, the resistance will be effective and the blight thrown off: if it is, from any cause whatever, weak and non-luxuriant, the alga gains the day, the shoots die, and the bushes hence cease to yield. It is essential to insist more than ever that *Red Rust is a disease of weak plants*, and that the primary aim of every planter who wishes to check the disease should be to strengthen the bushes, to seek out and deal with the causes of weakness—as otherwise every direct effort against the blight is bound to fail.

The method by which the plant attempts to check, and in many cases, does check the growth of the alga, is well illustrated in Plate VI. As the penetration of the blight into the bark gets deeper and deeper, the plant forms in front of the invading algal cells, a layer of its own dead cells, which form, so to speak, a fortification against their further penetration. In the figure this layer is shown by the darkened cells, and if it is sufficiently resistant the alga ceases to penetrate, the upper layers of the bark only are lost and the plant throws off the disease. Cases in which this has occurred can often and easily be found on almost any garden. If, on the other hand the algal cells succeed in getting through, another similar layer is formed deeper in the tissue, and the struggle re-commences. The ultimate result in a very large measure depends on the vigour of the plant, but, speaking generally, it may be said that if the plant is healthy and luxuriant the chances are in favour of the tea shoot.

Methods of Distribution of the Disease.

The next point to consider is how the disease is spread. The algae, as a group, are most commonly carried by water,—that is by rain. And up to a certain point this is the case with the present one. Where rain falls on an affected bush at the time the spores are ready to germinate, this rain, as it runs down the bush, carries the spores with it either from the leaf form or from the upper part of the stem lower into the bush. We are inclined to believe that, in very large measure, the old stems, when affected, are often infected by this method. That this kind of infection does take place, we have been able to prove by actual experiment,

In a few cases an affected leaf, or a bit of affected bark, drops direct on to a stem and infection takes place. We have been able to infect stems artificially also by this method.

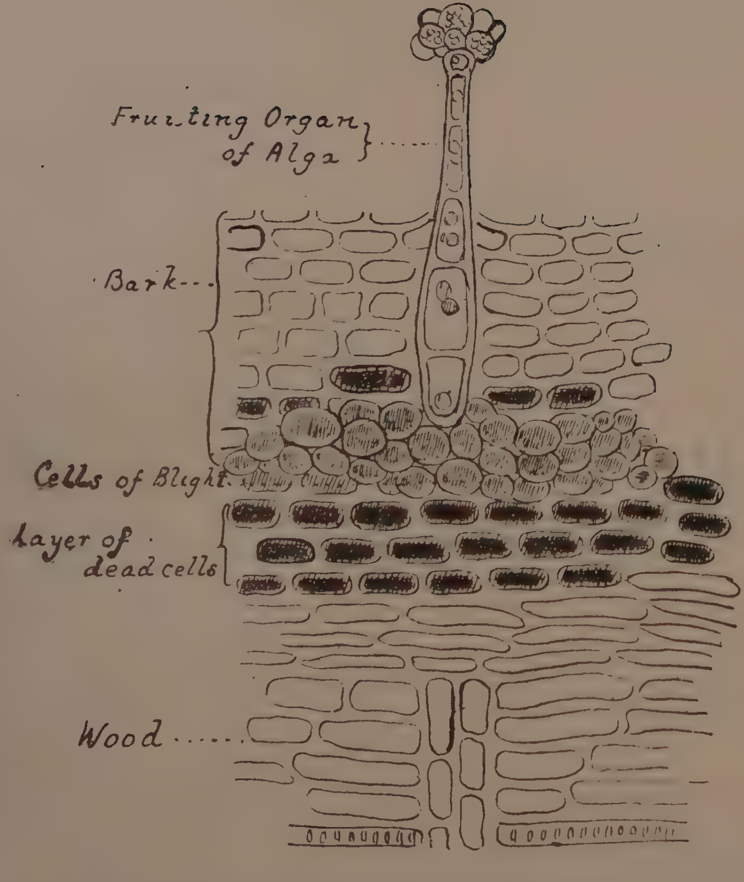
But by far the larger proportion of infection takes place by spores carried by the wind. In our experiments we have obtained spores, kept them dry for ten days, and carried

To face Page 8.

PLATE V.

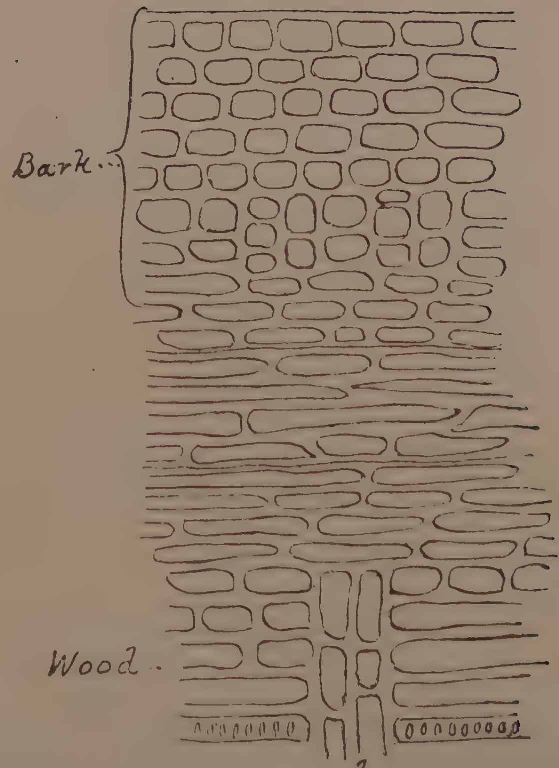
The effect of Red Rust on the growth on an unpruned tea bush in June 1904

PLATE V.



.a.

FIG 1.—Microscopic appearance of a cross-section of shoot attacked with Red Rust.



.b.

FIG 2.—Microscopic appearance of cross-section of a healthy tea shoot.

them about and yet they germinated at once when a drop of water touched them, and formed a new patch of blight. What we have been able to do artificially no doubt occurs in nature. We were even able to demonstrate that the atmosphere over a badly blighted garden contains abundance of spores flying about. These, settling on leaf or stem, at once germinate if rain follows and they get wet, and a patch of disease is the result.

SUMMARY.

With regard to the blight itself it may be regarded as established.

(1.) That the spores of the alga are carried by the wind principally (but also by water), more especially during June, July and August, and these, settling on the irregularities of the young tea bark, or on the surface of the leaves, determine the production of new patches of disease.

(2.) That the Red Rust patches on the stem noticed in April, May and June of any year are caused principally by infection in the previous rainy season.

(3.) That the alga grows on a multitude of trees in the jungle, both in the leaf and in the stem forms, and that since the spores may be carried to a considerable distance by the wind, it is almost hopeless to attempt to keep the blight out of a garden. Attention should be principally directed to bringing the bushes into such a condition that the blight will not seriously injure them, and to stopping, as far as possible, the ravages of the blight on tea which has shown itself specially susceptible to this disease.

CAUSES PREDISPOSING TO ATTACK.

We have said that Red Rust is essentially a blight of weak bushes, and that the primary object of a planter should be to make the bushes strong if he wishes to avoid the disease. But what are the conditions which lead to such weakness as would cause an excessive development of the blight? These conditions can only be determined by noting in gardens lying close together, some of which are seriously affected while others are not, the differences between the tea, the soil, the attention, the manuring, the pruning, and the plucking

on the various properties. In a large measure we have been able to do this, and now propose to describe shortly those conditions which we have noticed to lead to defective vitality and hence to a development of Red Rust.

Defective Soil and Sub-soil Conditions.

The first of these conditions is one on which we specially insisted in the former edition of this pamphlet,—a state of things whose influence is paramount in Nowgong. In that district there is little doubt that the cause of the excessive prevalence of the blight lies really and primarily in the defective soil conditions. As occurring on the worst gardens, the soil may be described as a rather heavy loam, dark-brown when wet, greyish when dry, containing much more clay than is usually found in the best tea soil. The surface is fairly friable down to a depth of say eight to ten inches,—just so far, in fact, as the cultivation extends. Immediately below this is a hard impermeable clayey sub-soil forming what is usually known in agriculture as a 'pan.' Below this again is sometimes a slightly softer clay interspersed with fragment of dark-red rock: in other cases the hard clay 'pan' descends to a considerable depth. The most seriously affected places have none but surface drains. The results of these conditions are—

(1). Owing to the 'pan' immediately below the cultivated depth and to the absence of drains, the top layer is nearly always (except in the rains) too dry and the lower layer too wet. As an example of this condition of things we may say that a determination of moisture made in the sub-soil at 3 feet deep in December 1900, when the surface was dry and powdery, gave 20lbs. water to the cubic foot, the total amount which it could contain when saturated being 27lbs. This water was unavailable because of the more or less impermeable 'pan,' and even were it available roots could not penetrate a soil so near saturation as the above figures show.

(2). Plants growing on such a soil are almost entirely dependent on the surface layer for moisture and for food, and their root development is almost entirely a surface one. This is found to be strikingly the case when bushes are dug up for the purpose of observation. Plate VII, Figs. 1 and 2, from actual photographs, show what really is the case. The root system consists of a spreading shallow mass of roots such as might be quite admissible, if sufficiently manured, in a climate where the soil is

Fig. 1.—Root development of bush on very hard subsoil.

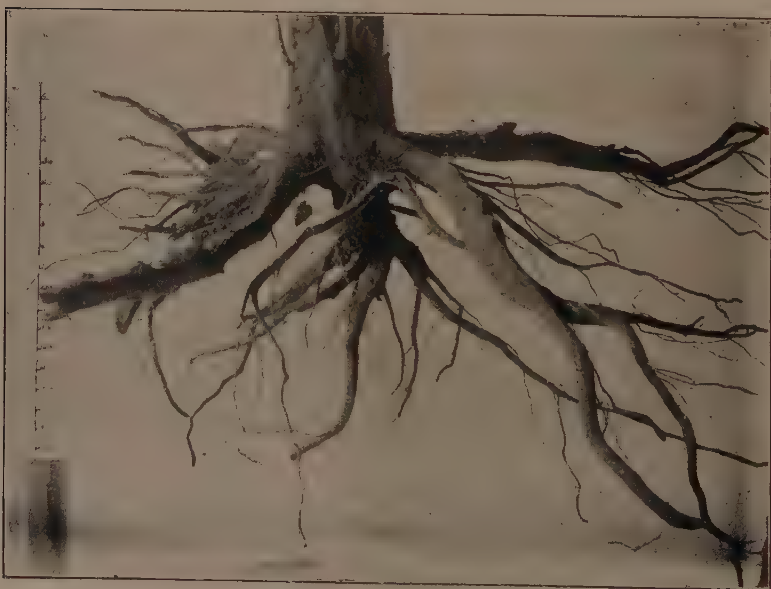


Fig. 2.—Root development of bush on very hard subsoil.

always moist, but which is entirely out of place in a situation experiencing long droughts such as prevail in Nowgong and in many other parts of the tea districts. In the particular instance in question, the cause of the failure of the roots to descend was rendered certain by an examination of the roots themselves. In one case a root was observed proceeding directly downwards, but on reaching the hard layer of soil in question, it suddenly was bent back on itself and came up again. Another root penetrated the layer for a few inches becoming very rapidly thinner during the process, and then split into two, both of which went no further down, but only horizontally for a short distance. In the gardens where these observations were made, the extreme depth to which the roots penetrated was only from eighteen inches to two feet in the soil.

These conditions are of course most unhealthy, and by a series of comparisons of bushes on lighter soils with light sub-soil well-drained with those growing as above indicated, in the same district, we are convinced that on many gardens the unsuitability of the soil conditions is at the bottom of the susceptibility of the plants to the blight Such conditions do not only occur in Nowgong : they are also found on many of the low lying clay flats of Cachar, many of which were called bheels on being opened out in tea ; they exist, in fact, in isolated gardens all over the tea districts and while they proclaim a soil not particularly suited for the tea plant in any case, they also indicate the necessity, now that the plant is there, of adopting every feasible method to increase the depth of the roots and the root development in every respect.

The primary means of increasing deep root development is by deep draining. The worst gardens for Red Rust that we have seen have been undrained, badly drained, or drained only recently The only gardens with the soil conditions described that we know, where the blight has been regularly fought and seems in a fair way to be brought under control, are where drainage has formed one of the main lines of attack. The effect of a correct system of drainage is to remove excess of standing soil water, and in many cases it may be said that the depth of possible root development is determined by the depth of the drain. It has been argued that owing to the short rainfall in Nowgong, drainage can hardly be needed there. As a matter of fact, there is no district in the Assam Valley where it is more needed, for there the soil is stiffer and less permeable than is usual in the valley and consequently

a hard 'pan' is apt to form at the depth of the annual deep hoeing, below which is water which only very gradually gets away. The effect of drainage to three feet six inches is very quickly visible, and this alone will lead to very extensive increase in root development. Probably one bush will be able to utilise more than double the soil in such land when drained that it is able to use in the same soil undrained.

But drainage having been carried out, the greatest effort should be made to force the plant to utilise the new soil put at its disposal sometimes by very deep cultivation down the rows, or what is probably in many cases even more useful, trench cultivation down the middle of the rows,—say in alternate rows each year. When plants are already in a not very vigorous state, excessive deep cultivation over all the land is a system which should be applied with a good deal of caution. Thus, for instance, if a plant has become accustomed to a shallow root development for many years, and then, being in a feeble state, is cultivated suddenly all over to a depth of fifteen inches, and thus the root system largely destroyed, it is often the case that the weak plant cannot re-act against the shock, it hardly forms roots again at all, and is in a much worse state than at the first. If the bush is strong enough to re-act against the cutting, it is quite probably as good or better than ever before, but the application of a radical change in method of dealing with old existing tea bushes is one to be made gradually, if possible, with as little injury to the existing root development at one time as may be.

Other methods of breaking up a hard soil are given by the use of 'Sau' trees (*Albizzia stipulata*) and by the repeated growing of green manuring crops of which the most suitable has been found to be the 'mati kalai' (*Phaseolus sp*). The effect of these methods is very great when long continued, but they must not be expected always to produce marvellous results at once, and present experience with regard to the 'Sau' tree seems to point to its being little use till it has been in the land quite a number of years.*

As we have already stated, it has been objected that Sau trees are themselves attacked with Red Rust, and may therefore be a means of seriously spreading the blight. The fact that Red Rust occurs on them is perfectly true ; that they take a great part in the

* One of the authors has dealt with the method of improving soil conditions in a more thorough manner in "The Tea Soils of Assam," Calcutta, 1901.

spread of the disease is more than doubtful. We base this opinion largely on the fact that the bushes round the Sau trees on badly affected gardens are nearly always healthier and contain less blight than the remainder of the plots. Whether this be due to the shade, or to the enrichment of the soil by the trees, or to some other cause unknown, we are unable to decide. The fact remains that in precisely the situation where the blight would be most prevalent if it were spread by the trees, the tea is less attacked. At the same time it would probably be wise to try to spray the Sau trees in a badly affected plot by the method recommended later in this paper. On no account can we, on present evidence, recommend the removal of the trees unless they have been planted very much too thickly in the garden, that is to say at less than forty feet apart.

Lack of Cultivation.

To this point we have dealt with the effect of unsuitable impermeable sub-soil. Often in under-laboured gardens, equal damage is done, from a Red Rust point of view, by lack of surface cultivation. The rapid and astonishing increase in Red Rust so soon as cultivation begins to be neglected, is very striking. This occurs not only when the land grows much jungle, but also when few weeds are found and the land becomes merely hard and compacted together.

The precise cause of the effect which cultivation produces on the bushes has never been entirely explained. Its primary object is, of course, always held to be the burial and destruction of jungle growth. But it must do more than this, for, in places, as we have noted above, where jungle growth is very small, the effect of lack of cultivation is equally obvious in a rapid yellowing of the bushes and a rapid increase in disease. In a large measure, no doubt, the cultivation is useful because it keeps the surface soil loose, and allows the tea rootlets thus easily to push through it. There is, we fancy, something even beyond this. In heavy soils, at any rate, there is always a large amount of plant food in the soil that no plant can use as it is not in a condition in which it is absorbable by vegetable growth. This becomes only gradually available in the soil when it is exposed to atmospheric influences. A large quantity of the phosphoric acid and potash in heavy soils is usually in this unavailable condition, and it needs the exposure caused by the regular hoeing to make them ready to be absorbed by plant life. This is the more probable, because as land gets older and

longer under tea, cultivation becomes more and more necessary to maintain vigour in the bushes, and a garden which will, in its early days will, do well with four light hoes per annum, will ten years later need six or seven to give anything like equal results.

Then necessity for really good cultivation in a garden badly blighted with Red Rust cannot, however, be too much insisted on. Given an old garden with moderately heavy soil and little cultivation, Red Rust will most certainly be rampant everywhere. Very often, as has most remarkably been proved in one case during 1904 on the Tezpur bank, the same garden will be enabled to considerably reduce the disease if the regular deep and light hoes of the season are given in an adequate and thorough manner combined with other changes in treatment necessary in the particular case.

While on this point we cannot refrain from referring to a controversy which has recently arisen as to the value of hoeing a garden in the latter part of a season, say from August onward. Our own idea is that such cultivation is extremely valuable, and largely from considerations not of the results for season in which it is done but rather of the following one. At this time the Red Rust is growing on the stem. If one can give the bush enough vigour to stop the progress of the blight then (see page 8), the number of dead shoots on this account in the following May and June will be much diminished and new growth arising from them will be giving leaf in the following season. It may generally, we think, be said that any lack of hoeing in the latter part of one season is likely to be felt in susceptible gardens by the occurrence of more disease, and hence the production of less leaf in the following season.

Exhaustion of the Soil.

A third cause of weak bushes which is liable to induce Red Rust, is merely exhaustion of the soil. Very often this is, as will be seen, merely a secondary result of the available layer of the soil being shallow through the existence of a 'pan' or of a very heavy sub-soil. In such cases, and in all cases where the soil is exhausted and the plants diseased on this account, manuring becomes of great assistance in fighting the blight. Examples of its effect on tea affected with Red Rust could be named in almost any district. Close by one plot in Nowgong, as poor, weak and rusty as any, a new set of coolie lines were placed three or four years ago. Now, the part round these lines, though it still contains a great deal of rust, seems to be resisting it with much greater vigour than

elsewhere, and it is here a rarity to see a bush of which half the foliage is killed in June—a common sight in the remainder of the section. Further, those gardens in the same district, with soil such as I have described as favourable to Red Rust, which have suffered least are precisely those on which manuring and top-dressing have been most systematically carried out. In our experiments in 1904, when the bushes were treated with castor cake (sixteen ounces per bush) at the end of April, they threw off the blight at a considerably earlier date than those in the adjoining rows which had received no manure.

Whether the land is suffering from exhaustion to a serious extent can generally be fairly well tested by finding whether it will grow a good crop of *mati-kalai*. If it does so, then exhaustion is probably not the cause of the Red Rust attack. If *mati-kalai* refuses to give a good crop without manure then the poverty of the soil will most likely be found at least to be a contributory factor in producing the disease. To specify what should then be done in any particular case demands an analysis of the soil and a careful examination of the circumstances. In any case such manures should be used as will give vigour to the bushes, as, for example, top-dressing bheel soil material if good—but only if it is really good: cattle manure at the rate of twenty tons per acre applied in February or March, especially if it has been kept under cover; mustard cake at the rate of eight ounces to the bush, castor cake six ounces per plant—and, in addition to each and all of these, the systematic use of *mati-kalai* as a green manuring crop in the year or years following the manure application. We fully believe that there are cases where the feebleness of the bush causing Red Rust is solely caused by the exhaustion of the soil which nothing but systematic manuring can cure.

Effect of Jat of Plant.

Some types of plant are more susceptible than others: this is a fact already well recognised in the affected districts. At the same time no variety of the tea plant known as yet seems to be altogether immune. It is wise, however, in those districts or on those gardens where it appears as a serious blight, not only in planting out new areas, but, what is even more important, in filling in vacancies in old tea and in replanting old tea, to use those types of plant only which are most resistant to the alga. Speaking generally, the pure Assam indigenous types have shown

themselves the most susceptible of all to the disease, and on the same garden, are much more badly attacked than either the hybrid or the Manipuri blocks. Even among the produce of different seed gardens of the Assam indigenous type, a marked difference in the susceptibility can be noticed. However useful these jats are where the conditions are really favourable, they should not be used, we think, in districts where Red Rust is known to be a constant menace,—in spite of their general reputation of producing much better tea. Between the 'Manipuri' and the best types of 'Hybrid' there seems not much to choose as to susceptibility to Red Rust. The term 'Hybrid' is, however, so indefinite that general statements with regard to it are almost worthless. The 'Manipuri' or the 'Manipuri once removed' seem to possess very great advantages for filling in vacancies, for replanting old tea, or for growing in districts much subject to the disease. The difference between blocks planted with Assam indigenous and 'Manipuri' on some gardens in Nowgong and in Sylhet where the disease is serious, is so marked that after seeing them there could remain no doubt as to the advantage in respect to health of the bushes obtained by using the latter there. The various marks of the 'Manipuri' jat are undoubtedly what should be planted out in such districts.

Effect of Pruning.

The effect of pruning in increasing or diminishing the weakness of the bushes in any garden and hence the amount of Red Rust, cannot be exaggerated, and the more the problem is studied the greater its influence seems to appear. This is only natural from the nature of the disease. It is obvious, from what we have already said, that the weaker the shoot in a particular bush, the more likely is it to be attacked and killed by the blight, and consequently to continue the destruction caused by the alga from season to season. Now in the pruning in vogue in many districts and especially in the so-called 'table-pruning,' the weak shoots remain in the bush all over. In addition to this the shoots at the edge of the bushes (which are always weaker than those in the centre) are not only left in the bush but are left with a longer length of new wood than the stronger ones nearer the middle, and, if short, often do not get pruned at all. Thus the very shoots which carry most of the alga in a flourishing condition are, under

such pruning, precisely those which are given the opportunity of spreading it.

What are then the means of avoiding such a state of affairs? There is little doubt about the answer—*clean* pruning, and pruning the new shoots to an equal length all over the bush. By clean pruning we mean that every shoot which will obviously not give a strong new shoot for the following season should be removed from the bush. Such pruning, usually called 'cleaning out' by planters, appears advisable entirely apart from any consideration of Red Rust, but when this disease is present seriously it seems not only advisable but indispensable. The weak twiggy shoots contain most of the Red Rust; they will never throw out good new wood: hence both from the point of view of the yield of the bushes and the removal of disease such shoots should be removed. One cannot too much insist on this point in connection with the disease in question. Cheap unclean pruning is a very great mistake in a garden seriously attacked with this blight. At the same time there is danger in going to the other extreme. Too much 'cleaning out;' the removal of leaves for its own sake: the cutting out of shoots which are likely to produce good growth in the year following:—all these are equally dangerous with the practice of leaving useless, thin, twiggy shoots in the bushes. Such, too drastic, treatment removes the leaf growth which forms, as it were, the lungs of the bush, and which should, hence, never be taken away without very good reason. Cutting out too little or cutting out too much is equally dangerous and has a tendency to reduce the vigour with which the bush resists the Red Rust disease.

We have pointed out, moreover, elsewhere, that the longer the growth left on a new shoot in pruning, the less vigorous, other things being equal, will be the shoot which is thrown out from it. Now if a bush be cut flat over the top, it is obvious that the weaker shoots at the side of the bush are left considerably longer than the stronger ones in the middle. Such a method tends to increase the weakness of the sides relatively to the remainder of the bush, and hence tends to greater susceptibility to Red Rust. Now it is well known that this disease is actually much more obvious round the edges of bushes than in the centre,—and, we may add, it is much more noticeable round the edges of bushes pruned by the flat-top system of pruning. We would urge most strongly that, even if the system costs more money, on any garden where Red Rust is serious, clean pruning should be adopted, com-

bined with cutting the new growth on the sides of the bushes only to the same length as in the centre of the bush.

There is another point also dependent on the principle that the longer the growth left in pruning the weaker will be the shoot produced. It would seem to be wise to leave the least amount possible of new wood on the bush. Actual experience proves the point. One of the authors was called to see a garden some time ago on account of its suffering from a severe attack of Rust, and there seems no doubt that the principal exciting cause of the attack in that case was the consistent leaving on too much wood in high pruning. Four inches had, in fact, been left each year. The same tendency to produce weak shoots and hence to contract Red Rust was the result and the method had been in force so long that hard pruning of a large part of the garden was absolutely necessary.

So far as ordinary high pruning, in connection with Red Rust, is concerned, we may summarise by saying that in every garden seriously affected or threatened with the disease, it is almost imperative :—

(1) to prune 'clean' removing obviously *banjhi* twigs all over and throughout the bushes.

(2) to prune the sides leaving not more wood per shoot than is left in the centre of the bushes.

(3) to prune short, leaving two inches of new wood as a maximum.

Heavy Pruning and Red Rust.

We now come to a consideration of the relationship between heavy pruning and the disease. Before so much was known about the blight there was really only one method in vogue for dealing with tea in the condition which we now know is caused by Red Rust. This was to heavy or collar prune the number. The method is still often applied and in many cases is the only possible treatment, as well as the proper one. But to be successful, the causes which have led to the rusty condition of the bush must have been removed, and this is precisely what in many cases has not been done. A case comes to mind, seen during the present season (1904), where extensive collar and heavy pruning has been undertaken during the past few years. Certainly the bushes needed it, for

they had hard stems, contained many dead shoots at the middle and end of the season, were affected badly, as a rule, with Red Rust, and were, in general, in a hide-bound, unyielding condition, largely through repeated attacks of this blight. The result of the collar pruning and more especially of the heavy pruning (which was done with more or less of manure) was to give a very healthy growth during the first season: this was pruned down to about twelve inches if collar-pruned, or other measurement if only heavy-pruned, and the following season the outer twigs had Red Rust on them again, and the amount increased in each succeeding year. This attack kept the bushes small, preventing them, by constant destruction of the outer shoots, from ever reaching the size of those which had been removed by the collar pruning. Thus the yielding bush area was permanently reduced, and the smaller bushes are rapidly again becoming a prey to the disease.

The case we have here described is by no means unique: similar ones occur in most districts where heavy pruning has been somewhat rashly adopted as a cure for Red Rust, without previously securing that other conditions of soil, of sub-soil, of cultivation, of manuring, were sufficiently satisfactory. It may, in fact, be said that heavy pruning of any sort is only a very temporary and partial cure of Red Rust, and may result in permanent reduction in the size of the bushes, unless the other necessary conditions mentioned are secured before such heavy pruning takes place.

Effect of Bad Plucking.

In enumerating to the causes of weakness in a tea bush, we have only now to speak of bad plucking. The form in which this occurs is usually that of too close plucking in the early part of the season. The effect of such a method takes place in the following manner. The amount of leaf which can be produced in the season by any bush, depends very largely on the breathing area, *i.e.*, the leaf surface on the bush. If this is diminished too far, the leaf produced will be less, and, furthermore, the shoots bearing the leaf will be starved and thin. Now this is just what happens if the bushes are plucked too close at the early part of the year. The amount of young leaf, through which the plant breathes, is reduced, the wood gets thin, the yield gradually falls off, the bushes become the prey of Red Rust. Such has been the sequence in quite a number of gardens in the Dibrugarh district, and often, in attempting the remedy the resulting

unyielding bush, this has been cut down, and hard plucked once more, after having grown up into a good bush again, with the same sequence of results. Such gardens and parts of gardens gradually become almost irrecoverable from many causes, one of the principal of which is Red Rust following weakness induced by over hard plucking in the early season. Such hard plucking is now uncommon, but the danger of increasing blight by its adoption must be super-added to arguments against it on other counts.

SUMMARY.

Thus we may summarise the principal conditions which may lead to an excessive development of Red Rust, because they bring about weakness in the bush, as follows—

1. Hard pan in the sub-soil, or, more generally, unhealthy subsoil conditions. These lead to the formation of roots near the surface only, resulting in susceptibility to drought, and to exhaustion of the limited soil available for feeding purposes. These conditions, which lead to the blight becoming serious, can largely be counteracted by—

(*a*) drainage—deep drains not less than three feet deep, and banked up to prevent surface drainage into them, are necessary.

(*b*) deep cultivation, leading to the forcing of the roots into a lower layer, or trenching between the rows still deeper, which has the same effect. These methods should be applied with considerable caution in old tea and never, if such cultivation has not been done before, without manuring.

(*c*) growing deep rooted trees among the tea.

(*d*) green manuring with *mati-kàlai.*

These last two methods only act gradually and not very much, probably, during the first year they are employed.

2. Lack of cultivation. This leads to the choking of the tea roots by jungle roots, to the hardening of the soil and hence to the stoppage of the delicate tea roots from searching for food, and to the arrest of the changes in the soil, which cause increased availability of the plant foods in the soil. This condition can only be

counteracted by better and more frequent cultivation, and by the use of green manures.

3. Exhaustion of the Soil. Where neither of the above causes are at work, there is reason to ask the question as to whether the soil is not exhausted. If this is found to be the case, manuring must be adopted, and adopted at once, or else other means of improving the tea and getting rid of the disease will be found in very large measure to fail. Analysis of the soil is usually needed to determine what manures will suit best in the particular case, but for most soils exhausted by tea we have found nothing better than cattle manure or oilcake,—both succeeded in the following year by green manuring with *mati-kalai.* A very small dressing of cattle manure (say two tons per acre) has been found very successful in sandy land in securing a good crop of *mati-kalai* and so obtaining the full manurial value of this latter.

4. Susceptible type of plant. The pure Assam indigenous jats of tea are considerably more sensitive to Red Rust than the Manipuri type. Therefore under conditions known to be favourable to this disease or in filling in vacancies the latter should be preferred.

5. Incorrect pruning. In ordinary annual high pruning this incorrectness may consist in—

a. leaving weak shoots in the bushes which ought to be removed, and which, besides weakening the remaining shoots, form a fruitful means of carrying over the disease from season to season.

b. cutting the shoots at the outside of the bush longer than those in the centre (table-pruning) and hence leading to the production of weaker growth in this part of the bushes.

c. cutting the shoots too long. Not more than two inches of new wood should be left as a maximum.

6. Unwise heavy pruning. This may be said to occur when it has not been ascertained that the soil conditions are such as to allow of this operation being successfully performed, or, if ascertained, they have not been improved previous to the pruning.

7. Too close plucking in the early part of a succession of seasons.

Direct Methods of Attacking the Blight.

Such are the principal causes of weakness in the tea bush as grown in India, and hence the contributory causes of Red Rust. We believe that if due attention is paid to them from the beginning there will be little need in most cases of direct attack on the blight itself. There are many cases, however, where the disease has got such a hold over the bushes that it cannot be expected that any alteration of previous treatment will get rid of the Red Rust, though such alteration may make it much less serious. In the past many such direct methods of attacking the disease have been recommended. some of them of the most drastic character. The great question in a case like this, is whether, if these drastic methods are adopted we have any guarantee that the disease is really eradicated, or whether milder methods will not bring about the same result. We have been able to test the action of some of these methods on actually affected plots of tea, and we may now set down here the results.

Collar-Pruning as a Remedy.

In the first place collar-pruning has been suggested, combined with the complete burning of all the prunings as the best means of completely eradicating the blight. The possible result of such a method of treatment has been already described. In Nowgong bushes collar-pruned in the cold weather 1899-1900 were found seriously affected in 1901; in Sibsagar bushes collar-pruned in 1902-1903 were found with Red Rust on them in 1904. Such cases might be multiplied indefinitely, and it may be said with certainty that the utmost collar-pruning can do is to give the bush a chance to throw out healthy new wood all over the bush,—which, however, will only remain healthy and free from rust so long as the growth is itself strong, and the other conditions which favour the health of the bush are satisfied. The nature of the blight, blown about as it is by the wind, and carried by rain, would suffice to show that the eradication of the blight for any long period could not be expected from collar-pruning alone.

Cutting out Affected Twigs.

Perhaps the favourite method of attempting to deal with the blight in the past has been to cut out all the affected twigs when the red patches become obvious in the months of April and May. From what has been described if the life history of the blight, it would be hardly expected that this method would have any real

effect on the disease, as the rust which becomes visible to the eye in the spring has, in most cases, been in the bush for six or seven months, so that it is a case of shutting the stable door after the horse is stolen. A careful test was, however, made during the present season in Nowgong, and in a selected series of bushes all the twigs which were affected to the naked eye were cut out by women early in May. The futility of the operation was obvious at the time, for although the women employed cut out every vestige they could see, yet with a powerful lens it was possible to see the blight on at least an equal number of shoots left in the bush. These would, in ordinary garden practice, remain in the bush. A fortnight afterwards (May 30th), forty per cent. of the bushes so treated were obviously again attacked, and variegated leaves had again appeared. Three months later, the bushes presented no different appearance from that of adjoining parts of the plot where the rust had not been cut out except that the growth was distinctly thinner. As a result, therefore, of studying the subject from every aspect we have come to the conclusion, that, provided the conditions are otherwise favourable to the blight, cutting out the rust, in any way, alone, without further treatment, is of little or no use.

Spraying.

The usual method of attacking algal and fungus diseases of plants is by a method of spraying, the favourite material for this purpose is the so-called "Bordeaux mixture" composed of Sulphate of Copper and Lime. Experiments conducted in 1901 led to the view that even in the seeding stage Red Rust was quite killed by spraying with this material, as well as by Sulphide of Potassium, which was used as an alternative. And this is undoubtedly the case if the spraying is thorough enough to wet all the fruiting filaments. Under these conditions a microscopic examination of those parts of the blight still remaining on the bush showed the contents of the heads of the filaments to be shrunken, and the spores found there to exhibit no motion as in the case of the living *alga*. The visible structures were, therefore, dead. After leaving the mixture on the bushes for ten days the branches were again examined, and the few filaments of the *alga* remaining had, by this time, quite changed colour, becoming almost white, and were evidently quite ruined.

These were experiments only, and as soon as it was attempted to put the method in practice on a large scale, difficulties arose and the results were not nearly so good. The reason of this has been found during the past season. Spraying with Bordeaux mixture

and with Sulphate of Copper respectively was done on two affected patches on May 17th, 1904, in a similar fashion to that in which it would be carried out in practice. On examination of the plot treated with Bordeaux mixture on May 25th some living rust patches were found, in which the outer parts of the patch were destroyed, but the centre had succeeded in throwing off the spray, and was then bearing living fruiting filaments. The same was the case, to a less extent, with Sulphate of Copper, and was evidently the result of a certain oiliness of the filaments which had prevented them being wetted by the spray.

This result would be very serious if the season when the red fruiting patches can be seen were the best time to treat the bushes. But it is not. Already in 1901 we recognised that spraying in May and June was impracticable, however, effective it proved to be. We have become certain that young shoots, at any rate, which bear fruiting patches at this season are doomed to die, whether the *alga* on them be killed or not. And it is now evident that if sprays are to be effective as a curative method they must be applied, if applied at all, during or soon after the pruning season. At that time the *alga* is growing in the stems but has not reached, in most cases, the stage at which the shoot is inevitably killed. Moreover, Dr. Butler, working at the Botanical Gardens, Calcutta, has found that the *disc* of the *alga*, as it exists at that time is exceedingly absorbent of liquids, and hence of the Bordeaux mixture or other spray used. We are, therefore, very much in favour of using spraying methods on badly affected plots and in other special cases, but of using them immediately after pruning during the cold weather.

The cases in which we should strongly urge the spraying of tea would be the following :—

1. When a plot is badly affected with the disease, and, while methods are being taken to make the bushes stronger, it is decided to up-prune the plot. In this case the useless wood and twigs should be thoroughly cleaned out, and immediately followed by spraying with Bordeaux mixture.
2. The year after collar-pruning, or heavy pruning, when the bush is pruned back, the bushes should be sprayed immediately after pruning, on any affected garden.
3. In cases of bad attack where middle-pruning is carried out, and the wood left is liable to contain the disease,

spraying should be carried out as soon as the pruning is accomplished.

In our experiments the results obtained by using Bordeaux mixture have been very preferable to those with Sulphate of Copper alone, and we, therefore, recommend this material for such spraying as may be done. It should be made as follows :—Dissolve three pounds of commercial Sulphate of Copper in twenty-three gallons of water in a wooden tub (not in a metal vessel). In another vessel slake three pounds of quicklime, freshly burnt if possible, in two gallons of water. This lime should form, with the water, a turbid smooth liquid without any lumps. Finally add, gradually, through a fine mull-mull cloth, the lime liquid to the Sulphate of Copper solution, stirring meanwhile. When thoroughly mixed, the liquid is ready for use, but must be kept stirred up.

As far as a spraying pump is concerned, we have found Gould's Standard Spraying Pump fitted with two twenty-foot leads of hose and Vermorel nozzles, used attached to a ten-gallon oil drum, the best we have tried as yet. This requires a staff of one man pumping, two men spraying, two boys holding the hose, one man making the liquid, and one man carrying the liquid to the pump, or a total of five men and two boys. At least three acres should be covered in one day, using up one hundred and fifty gallons of mixture per acre. The total cost of the application at this rate will not much exceed six rupees per acre.*

But we must insist on the point that in spraying against Red Rust the time of the year at which it is done is everything. As we have shown, when the red fruiting patches appear on the stem the shoots are already as good as dead, and the sprays are not easily absorbed by the *alga*. Three, four, or five months before the conditions are quite different. True, the blight cannot then be seen with the naked eye. But the *alga* is at that time quite absorbent and its progress has not been great enough to lead necessarily to the death of the shoot. Therefore, if spraying is to be useful at all, it should be carried out during the cold weather, after pruning, and not when the blight is apparent, with its red patches, on the stem.

It is well known that young plants used for filling vacancies in old tea are almost invariably attacked with this blight during their second season of growth, and before they are cut down to six inches

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* The present price of Sulphate of Copper (commercial) is about Rs. 26 per cwt. f.o.b. Calcutta.

as is now usually the case at the end of that time. A much more healthy bush would most probably result if this attack could be avoided, and it *can* largely be avoided by dipping the whole seedling, one year old, before being planted out into Bordeaux mixture. This should, we think, be done in every case, whether the seedling is blighted or not. The trouble and expense is small, but it is a safe-guard which one cannot afford to neglect, both for the sake of the seedling and for that of the garden round it.

CONCLUSION.

Though investigations have thus succeeded in clearing up much that has been mysterious about the origin, development, and prevention of Red Rust, much remains to be done. We have still no certain knowledge as to whether the time of infection is quite limited to the part of the year we have indicated; we are ignorant as to whether the length of life of the form on the leaf is so short as to make this a serious means of spreading the disease in a garden: we do not know why the red patches suddenly appear in a garden where hardly any were previously apparent, after the first rain in the early part of April: we are not sure whether infection may take place direct from other plants on to tea without difficulty; and many other points are disputed or disputable. But at the present time some clear practical results are apparent. The disease is a disease of weak bushes: make the bushes strong and vigorous, and, though nearly always present in very small amount, it largely disappears as a serious blight. The blight, when seen in April and May, is in its last stage, and has been growing already in the bushes for many months,—and if attacked at all, must be attacked not when the red patches appear, but at a much earlier date. While there will probably be always a trace of it in many, if not in all gardens, it is only when unfavourable influences are at work—the principal of which we have indicated—that it becomes of serious moment. When it *does* become serious the most important matter would seem to be to at once search for such unfavourable influence, and remove it as far as possible,—using direct attack of the blight by spraying as a secondary means of getting rid of the *alga*. By these means, though certain districts and certain gardens will always be particularly liable to attack, it would seem probable that we shall be able to hold in check a blight which, if unrestrained, will inevitably ruin tea properties in almost every tea district of North-East India.

[1,000—23-12-1904.]

WITCH BROOM DISEASE OF CACAO.

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Trinidad

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The Witch Broom Disease of Cacao in Surinam.*

Introduction.

Among the diseases of tropical plants which have attracted the attention of pathologists within the past few years, the witch broom disease of cacao in Dutch Guiana is perhaps the most important, not only on account of the great financial loss which it has brought to the growers of Surinam, but because of its scientific interest as well.

Though the disease must have existed in Dutch Guiana for a long time, its serious nature was not recognised until 1895, in which year the growers in the Saramacca district spread abroad alarming news of its devastations. In this district it reached its greatest intensity in 1900; since that time the losses have abated to a certain extent. In the plantations further inland, along the Commenwijne and Surinam rivers, the seriousness of the disease was recognised a few years later than in Saramacca, and in these districts it reached its greatest intensity in 1904.

The following table, showing the annual exports of cacao from Dutch Guiana from 1899 to 1906 will give an idea of the damage caused by the disease :

1899	... ...	8,492,000 lbs
1900	... ...	6,439,400 ,,
1901	... ...	6,959,700 ,,
1902	... ...	5,181,440 ,,
1903	... ...	4,942,740 ,,
1904	... ...	1,878,800 ,,
1905	... ...	3,699,960 ,,
1906	... ...	3,257,320 ,,

In 1906 the disease was found by Bartlett in a plantation on the Demerara River, and since then it has been discovered on other estates in British Guiana. Up to the present time, it has not been observed in other cacao growing countries.

Bibliography.

For some time the planters of Surinam ascribed the disease to a great variety of causes, mostly physiological, such as poor soil, too much shade, or lack of drainage. Some believed that the curious growths, the so called witch brooms, were mere epiphytes, and not

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* Note.—Early last year the Director of Agriculture obtained permission from van Hall and Drost to reproduce in the Bulletin of Agricultural Information the plates illustrating their paper on the Witch-Broom disease of cocoa in Surinam. Soon after assuming the duties of Mycologist the writer was asked to prepare a short paper on the disease to accompany the plates. This was done, but owing to the delay in the publication of the Bulletin it appears now at rather a late date as a full translation of van Hall's paper together with the plates has recently been issued in the Proceedings of the Agricultural Society. It has been thought unnecessary to publish the plates again.

part of the cacao tree at all. The first papers of scientific interest dealing with the disease, are those of Ritzema Bos[a], in 1900 and 1901, in which he ascribed the disease to a new species of fungus, which he called *Exoascus theobromæ.* Unfortunately, this author's work was all done in Holland, with very poorly preserved material sent from Surinam, and is not at all convincing. Although subsequent investigators have found fungous threads in the diseased tissues, no fruiting bodies of the Exoascus type have been observed.

In 1901 Hart[b] sent material to Kew and to the Imperial Department of Agriculture at Barbados. That sent to Kew was examined by Massee, but the results were negative as far as the identity of the fungus was concerned, as no fruiting bodies were present. Howard[c] examined the material which was sent to Barbados. He found no Exoascus, but a species of Fusarium fruiting on the bark, which he stated might have some connection with the disease.

Went[d] was the first pathologist to devote any great amount of time to the study of the disease. He spent six months in Surinam in 1901, and came to the conclusion that the disease was of fungous origin, and was one not only of twigs and branches, but of the pods as well. The latter, through the invasion of the fungus, became more or less distorted and finally hard and woody. Went was unable, however, to find any fruiting bodies of the fungus, so that he could not identify it.

Charles[e], from a study of dried material suggested that a species of Lasiodiplodia might be the cause of the disease.

In 1905, Dr. C. J. J. Van Hall, [f and g], the well-known Dutch pathologist, with the assistance of A. W. Drost, of the Agricultural Experiment Station, Paramaribo, began a study of the disease. Preliminary reports of their work were made late in 1905 and 1906, and a full report was published in 1907. The authors were unable to find any fungus of the Exoascus type, as described by Ritzema Bos, but confirm Went's supposition that the disease of the pods is caused by the same fungus as that which causes the witch brooms on the branches. Still further, they found that the fungus attacked the cushions, causing abnormal production of flowers, and finally they discovered the fruiting bodies of the fungus and described it as a new species of Colletotrichum, *C. luxificum.* They describe the different forms of the disease at length, and give the characteristics of the

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(*a.*) Ritzoma Bos.—Tijdschrift over Plantenziekten, 6 : 65—1900.
Zeitschrift Pflanzenkrankheiten, 11 : 26 30—1901.

(*b.*) J. H. Hart.—Trinidad Bot. Dept., Bull. Misc. information, No. 27, p. 328—1901.

(*c.*) A. Howard.—West Indian Bulletin, 2 ; 205, 289—1901.

(*d.*) F. A. F. C. Went.—Verh. Konig Akad. v. Wetensch, 2 sect. 10 : 3—1904.

(*e.*) V. K. Charles.—Jour. Myc., 12 : 145-146—1906.

(*f.*) C. J. J. van Hall.—Tropical Life, 1 : 12—1935.
2 : 83—1906.

(*g.*) C. J. J. van Hall and A. W. Drost.—Travaux Botaniques Néerlandals, vol. 4, pp. 77, 16 plates—1907.

fungus in detail; in fact, the whole paper is such an excellent piece of work that it is only to be regretted that the authors did not go a step farther and prove absolutely by a series of inoculation experiments with pure cultures, that their fungus is the cause of the typical witch-brooms, and that the "male" cocoa, star blooms, and indurated pods are all forms of the same disease [1].

The Possibility of Witch Broom in Trinidad.

During the past four months, the writer has visited a number of estates in various parts of the island, and in many places has found abnormal growths on cacao trees. The agricultural inspectors also, from time to time, have sent in for examination, specimens of such growths. On these various lots of material, the same fungus has usually been found, and microscopically it is very similar to Van Hall's *Colletotrichum luxificum* It has also been obtained from diseased pods. Considering these facts, it has been thought advisable to issue this preliminary Bulletin in order to call the attention of the planters to the disease, and to give them descriptions of its various forms, so that they will be better able to recognise it if present on their trees, but it must be understood that it has not been proved that "male" cocoa, star blooms, indurated pods, etc., are connected with Witch-Broom, and that typical witch-brooms have not been found in Trinidad. The serious proportions which the disease has attained in Surinam, is due primarily to the fact that it went for so long a time unrecognised, and had become widespread and had caused great loss, before any remedial measures were tried. The writer is carrying out inoculation experiments with the species of Colletotrichum which has been isolated from diseased trees and pods, the results of which will be reported upon later [2].

Description of the Disease.

The following pages give a summary of Van Hall's and Drost's description of the disease as well as the remedial measures suggested by them, and the plates are reproduced here with their permission.

There are three distinct external characteristics of the disease, namely, the witch brooms; the hardened fruits; and the flowers in star-like clusters.

Witch Brooms.

A typical witch broom is a dense broom-like growth brought about by an excessive growth of lateral shoots, together with a shortening of the internodes of the affected twig. The main branch of a cacao witch broom is two or three times the thickness of a

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(1.) Although Dr. Fredholm's translation reads that "inoculations have demonstrated that this fungus is the actual cause of the disease," no account of such inoculations is given, nor is there any proof given that the fungus referred to is Colletotrichum luxificum. To the writer's knowledge witch-brooms have never been produced by inoculations with a pure culture of either a fungus or bacterium.

(2.) As yet no definite witch-brooms or other abnormal growths have resulted from these inoculations. In some cases the species of Colletotrichum used has proved to be a rather weak parasite causing young leaves to wither and dry up and the fungus mycelium has at times been found in the leaf petioles of inoculated plants. Inoculations with it are still being made.

normal branch, especially at its base, and the surface is generally rough or wavy. The leaves of such a branch never reach normal size; but always remain soft and limp, and are often of a darker colour. The stipules, which normally drop early from the leaf bases, are abnormally large and persistent. Before this branch has grown out very far, the axillary buds begin to develop into lateral branches, so that soon a more or less typical broom-like growth is formed. Very few leaves are formed on the lateral branches, but the stipules are very noticeable. These witch brooms develop very quickly, but their life is short too. Soon after they have reached their maximum development, they begin to die generally from the base upward, and eventually dry up. After a serious outbreak of the disease, the trees have quite a considerable number of these dead brooms, and these offer a point of entrance for other fungous or insect parasites. The witch brooms develop not only on the ends of branches, but may develop from the lateral buds and from either young or old wood. Those which grow from the cushions may be considered as transformed floral branches,—in fact they often bear flowers along the hypertrophied branches.

Indurated Pods.

The hardening of the fruit was not connected with the witch broom disease for some time, being considered simply the black rot caused by *Phytophthora omnivora.*

The typical characters which these affected fruits show are a hardening of the infected region; small protuberances which appear on young or half-grown fruits; the hypertrophy of the peduncle; and the black colour of the diseased area. Many affected pods fall off when quarter or half-grown, and some reach maturity; but the beans from such pods are not of good quality and are light in weight.

Starlike Clusters of Flowers.

When a cushion becomes infected, the disease is made manifest by a sort of floral witch broom or star shaped cluster of flowers, brought about by an abnormal development of lateral buds just as in the vegetative witch broom. A great number of flowers are in this case produced, and among these are often one or several vegetative branches, which in turn are transformed into small witch brooms. As a rule no fruits come from these flowers in stars, but at times they produce small misshapen pods with no seeds, the so called "male" cacao. At times however, these flowers produce a small number of fruits which reach maturity, but they generally show infection in one way or another. In other cases the infected cushions give rise to typical witch brooms which often bear flowers along the branches.

Cause of the Disease.

As mentioned above the authors state that the cause of the disease is a fungus, the mycelium of which is always found in the witch brooms, hardened pods, and diseased flower clusters. Hyphæ

or vegetative threads of this fungus are easily seen with the microscope, extending throughout the diseased branches, and running out into the leaves and flowers as well. In the affected fruits, the mycelium is present in and about the diseased areas; and in the star-like flower clusters, it can be found not only in the floral organs but running back through the peduncle, or flower stem, into the cushion. In the cushion, however, the mycelium seems to be short lived. By thoroughly sterilizing the surface of young pods, which showed the first evidences of the disease, and then keeping them in such a way as to be free from external contamination, the authors were able to obtain pure cultures of this fungus. Bits of branches from the young witch brooms were treated in the same way, and yielded the same fungus as the pods. On some of the cultures spore production took place, so that the fungus could be classified. It proved to be a new species belonging to the genus Colletotrichum, and the authors have given it the name *C. luxificum*. (The large group of diseases known as anthracnoses are caused by other species of Colletotrichum and of Gloeosporium, a closely related genus. The commonest examples here perhaps are the anthracnose ot mangoes and alligator pears.)

The authors found that spore production took place naturally, both on the hardened pods and parts of the witch brooms, under certain weather conditions. The sporulation on the fruits takes place most commonly just at the beginning of the dry season. The spore masses are somewhat pinkish and frequently are arranged in a circle about the diseased area. The disease is doubtless spread from tree to tree by means of these spores. During the rainy season, spores of another type are produced and these also aid in the spread of the disease. The spores can only infect very soft and young tissue, and it is only those reaching and developing buds or young stems, which cause the infections. After infection has taken place, the mycelium of the fungus develops rapidly in the tissues, and causes the characteristic hypertrophies.

The Effects of the Disease on the Cacao Tree.

Not only is the crop greatly diminished through the contamination of the fruit, but a large number of the trees become worthless or die as a result of the infection. Trees which are badly attacked produce only witch brooms and no sound growth at all, and such trees give scarcely any cocoa. When the witch brooms die the trees are left practically without any foliage and soon become a prey for boring insects and semi-parasitic fungi. If the trees are left moderately attacked they may throw off the disease, so to speak, but cankerous regions are generally left at the points where the witch brooms were attached. These diseased areas may heal over in time, but often they remain as open wounds and serve as points of infection for Chætodiplodia.

The disease has also caused serious damage to nursery stock, or to young trees which have been set out as renews. In such cases the whole top of the tree may be converted into a witch broom, or the abnormal growth may occur farther down the stem.

Predisposition to the Disease.

All the varieties of cocoa which are grown in Suriname, Criollo Forastera, Calabacillo, and Nicaraguan Criollo seem to be equally susceptible to the disease. Nor do external conditions, with the exception of the rainfall, influence the outbreaks in any way. The disease is found on trees grown at all altitudes, on all kinds of soil, and on well drained as well as on poorly drained land. It is prevalent on estates with no shade and on those with moderate or dense shade.

The disease has always been more severe in those years in which the rainfall has been quite evenly distributed throughout the rainy season, than in those with abnormally heavy rains followed by some days of dry and sunny weather.

Witch Brooms on Other Trees.

In connection with the work on cacao, the authors found witch brooms on both species ot immortelle, the mango and the mamee apple, but an examination showed that *Colletotrichum luxificum* was not the cause. Its parasitism seemed to be confined to the cacao tree alone.

Treatment of the Disease.

The methods of treatment which Dr. Van Hall recommends are very drastic, but are proving successful on those estates in Suriname on which they have been tried. The method is to cut off the whole crown of the tree by taking of all the main limbs two or three feet from the point of forking. The dehorned tree is then thoroughly sprayed with Bordeaux mixture. This work should be done towards the end of the dry season. Trees thus treated will form a new head in a few months. As the trees begin to grow again they should be inspected frequently and any witch brooms which are found should be cut off and burned, together with the cankerous area on the mother branch at the base of the broom. On plots of trees which were treated in this manner in 1905, careful records were kept of the yield in 1906 and 1907. Even in that short time the percentage of indurated fruits was very much reduced, and the total crop from the block of treated trees was more than twice from a similar block of untreated trees.

JAMES BIRCH RORER,
Mycologist.

August 6, 1909.

CACAO SPRAYING EXPERIMENTS.

James Birch Rorer.

Trinidad
Reprinted from Bulletin of Department of Agriculture, Vol. IX,
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Preliminary Report on Cacao Spraying Experiments.

ALTHOUGH the cacao spraying experiments have not been carried on for sufficiently long a time to make general spraying recommendations possible, the Board of Agriculture has thought it advisable to give at this time the beneficial and harmful results which have thus far been obtained together with the methods and mixtures used.

In the latter part of July some preliminary sprayings for the purpose of learning the effect of various mixtures on flower buds, flowers, young fruits, and leaves were made both at Santa Cruz and Tumpuna, while the main part of the work was done later in one of Mr. Maurice Lange's fields at the latter place. As a preliminary test Bordeaux mixture of two strengths, 5–5–50 and 4-4–50, was tried as well as a proprietary lime-sulphur solution at various dilutions. Both strengths of Bordeaux mixture destroyed buds and flowers and injured tender leaves on young chupons to a slight extent; but even the very small fruits and older leaves were not injured at all. The lime-sulphur mixture, diluted as much as 1 to 25 was also injurious to buds and flowers but proved innocuous to leaves and fruits, while at a dilution of 1 to 30, the weakest solution tried, the buds were scarcely injured at all and a few flowers which were open at the time of spraying set fruit later on. This mixture still more dilute is now being tried and may prove a valuable spray for cacao. A self boiled lime-sulphur mixture is also being tried. The injurious effect of the Bordeaux mixture was doubtless aided by the climatic conditions following the spraying, for a great deal of rain fell so that the trees were wet for several days. and it is a well known fact that Bordeaux mixture is much more injurious in wet weather than in dry.

For the experimental work on a somewhat larger scale a block of one thousand trees was selected and divided into two equal parts. The two plots of five hundred trees thus formed were as nearly alike as possible in all respects. The trees were of the same age, and the drainage, soil, and shade conditions of each plot was identical. Moreover two pickings which were made before any spraying was done gave practically the same amount of cocoa from each plot, and the relative proportion of black to good cocoa from each was the same. Plot 1 was sprayed on September 6 and 21 with Bordeaux mixture, 5–5–50 formula, while plot 2 was left unsprayed as a control. The spraying was done with a barrel pump fitted with two 75 foot leads of hose and 8 foot bamboo extension rods, with double vermorel nozzles. An endeavour was made to spray each tree thoroughly including leaves, pods, trunk, and branches. At the time of the first spraying the trees were well laden with young fruits from ½ to 3 inches in length and bore a few older pods. A small picking from the plots was made in September and the yield from each was the same, as was to be expected, for it was too soon for the

spraying to have had any effect. The two main pickings were made on November 12 and December 11. The fruit from each plot was piled separately. counted, and sorted into sound and black cocoa. The term "black cocoa" is used here in the general way and means pods which have been so attacked by fungi that the beans have been affected. Pods in which the rot started from bird, squirrel, or deer injury were not considered black cocoa in the count. Such injury was about two per cent. of the total number of pods picked. Detailed descriptions of various types of black and brown rots and canker of pods and of the causative fungi are in preparation for future publication. The results of the counts are shown in the following table :—

Plot numbers and treatment.	Pods Picked.		Total Nnumber.	Sound Pods.	Black Pods.	
					Number.	Percent.
1. Sprayed Sept. 6 and 21 .	Nov.	12 ...	1942	1726	216	11·1
,, ,, ,, ...	Dec.	11 ...	1277	1204	73	5·7
Total		...	3219	2930	289	8·9
2. Control, no treatment. ...	Nov.	12 ...	2064	1404	660	32·0
,, ,, ,, ...	Dec.	11 ...	1040	778	262	25·2
Total		...	3104	2182	922	29·7

From a study of the table it will be seen that there has been a gain both in the total number of pods and in the number of sound pods from the trees of plot 1. As a result of this gain the 500 sprayed trees yielded 189 pounds more of good wet cocoa than the unsprayed trees.

Although these results alone are not sufficient to make it possible as yet to give definite spraying recommendations, they show that the amount of black cocoa can be appreciably reduced by the use of Bordeaux mixture. Moreover both Bordeaux mixture and lime-sulphur solutions kill moss completely so that hand mossing is not necessary on sprayed trees; and again, trees sprayed with these fungicides are doubtless less liable to canker infection than unsprayed trees.

Method of Preparing Bordeaux Mixture.

It is essential that Bordeaux mixture be properly made to get the best results from its use. The necessary ingredients are copper sulphate or bluestone, temper lime, and water. The greater part of the commercial bluestone on the market here is suitable for spraying purposes. It should be obtained in either the crystal or granulated form; any which has a greenish substance mixed with it in appreciable quantities should be rejected. Great care should be taken to use only fresh temper lime. It can be got in barrels holding about 180 pounds or in smaller kegs. Soft water makes the best mixture, but for practical purposes any water which does not contain much mud or grit may be used.

Various strengths of Bordeaux mixture may be made. For general work it is perhaps best to use a mixture containing an equal quantity of bluestone and lime. In the experiments here the 5-5-50

formula has been used, that is to say, 5 pounds of bluestone, 5 pounds of lime, and 50 (American) gallons of water. A barrel of mixture after this formula should be made as follows :—Dissolve the bluestone in 25 gallons of water in a half-barrel or other suitable vessel; slack the lime in a similar vessel, and when thoroughly slacked and worked into a paste dilute with water to 25 gallons. Then pour the two solutions together simultaneously into the spray tank or other vessel. The mixture thus made will be a beautiful sky blue colour and creamy in consistency. It should be kept thoroughly agitated and used as soon as made, though the separate bluestone and lime solutions may be kept indefinitely. Where spraying is done on a large scale it saves much time to make up stock solutions of bluestone and lime. Fifty gallon barrels or puncheons of larger capacity can be used for holding these solutions. The bluestone stock is made by dissolving a given number of pounds of bluestone in the same number of gallons of water. This is best done by filling with water a 50-gallon barrel, if such is to be used, and suspending in it *near the top* a bag containing 50 pounds of bluestone. This will dissolve in about two hours. Each gallon of this solution will contain one pound of bluestone.

A stock solution of lime is made by slacking 50 pounds of lime in a barrel, and, when thoroughly slacked and worked into a paste diluting with water to 50 gallons. Each gallon of this mixture will contain one pound of lime. To make one hundred gallons of Bordeaux mixture of the 5-5-50 strength it is only necessary to take ten gallons from each of the stock solutions, after stirring them thoroughly, put into separate vessels and dilute each with water to 50 gallons. The whole of these dilute solutions, or equal portions of them as required, may then be poured together simultaneously through a strainer into the spray tank or other vessel. The strainer should be made of brass wire gauze of about 20 meshes to the inch. The thorough straining of spray mixtures is very essential in order to avoid the clogging of the nozzles with particles of lime or dirt.

The lime for Bordeaux mixture must be slacked carefully. The required amount of temper lime in lumps should be placed in the bottom of a barrel and enough water should be added to half cover it. The lime will soon begin to slack. More water must be added, a little at a time, and the mixture stirred constantly with a long handled shovel or other suitable implement. Too much water added at one time drowns the lime, while too little allows it to burn. When properly slacked it will be in the form of a smooth thick paste containing very little granular matter. Not more than 50 pounds can be well slacked at one time, and until the knack of working it is mastered it is better to start with 25 pounds or less at a time.

If possible it is best to get temper lime for spraying purposes in rather small quantities as it deteriorates very rapidly through air slacking, but if three or four hundred pounds are purchased at a time it should all be slacked as soon as received from the kiln. It may be slacked in 50 pounds lots, diluted with a certain amount of water and kept as a stock solution in barrels or large puncheons. In using such stock solutions it is only necessary to know the relative

proportion of lime and water and a Bordeaux mixture containing any amount of lime can be made. If a stock solution of either lime or bluestone is allowed to stand for sometime a certain amount of evaporation will take place Before using such solutions water should be added to make up the original quantity. The necessity of using good lime for Bordeaux mixture cannot be too strongly emphasized as not only the fungicidal value of the mixture but its sticking quality as well is greatly influenced by this factor.

Bordeaux mixture may be tested either with a steel knife blade or with a 10 per cent. solution of yellow prussiate of potash, but testing is never practiced in commercial operations and is not at all necessary if the lime used is of good quality and a quantity equal to the amount of bluestone is used. The object of the test is to ascertain whether or not all of the bluestone has combined with the lime, as uncombimed bluestone solution is injurious to plant tissues. If there is free bluestone in the mixture a slight deposit of copper will be seen on the knife blade after a short immersion in it; or a dark brown precipitate will be formed when a drop of the potash solution is added to the mixture. To the practised eye however the colour of the mixture alone is a sufficient guide, for if there is free bluestone present the mixture will have a distinct greenish tinge, while a neutral mixture or one containing an excess of lime will be sky blue. Bordeaux mixture must always be kept thoroughly agitated while being used.

Any inquiries in regard to spraying will be gladly answered by the writer.

JAMES BIRCH RORER,
Mycologist.

Since the above Preliminary Report on Cacao Spraying Experiments has been set up in type two more pickings have been made from the sprayed and unsprayed plots at Tumpuna. The results of the picking of January 14 were reported at the meeting of the Board of Agriculture on January 21, but the counts from that of February 15 are given here for the first time. The table already given, embodying the results of the earlier pickings, shows that the chief effect of the spraying was simply the reduction of black cocoa on the sprayed trees. This was again true in the more recent pickings, but in addition more pods were gathered from the sprayed trees. The following table shows the results of the pickings of January 14 and February 15 :—

Plot numbers and treatment.	Pods picked.	Total Number	Sound Pods.	Black Pods.	
				No.	Per cent.
1. Sprayed Sept. 6 and 21 ...	Jan. 14 ...	1,843 ...	1,713	130	7·0
" " " ...	Feb. 15 ...	986 ...	964	22	2·2
Total	...	2,829	2,677	152	5·4
2. Control, no treatment ...	Jan. 14 ...	1,159	881	278	23·9
" " ...	Feb. 15 ...	470	427	43	9·1
Total	...	1,629	1,308	321	19·7

From this table it will be seen that from the sprayed trees 1,200 more pods were gathered than from the unsprayed. This marked increase in number of pods coming at this time points rather conclusively to the fact that these pods were saved from fungus attack when they were quite small for the sprayings were made from 4 to 5 months before these pickings, and the life of a pod is from 130 to 150 days.

To the present time 1,315 more pods have been gathered from Plot 1 than from Plot 2; 7·3 per cent. of the total number from the sprayed trees was "black," while 26·3 per cent. from the control trees was "black." Owing to the reduction of black cocoa on the sprayed trees, 2,117 more sound pods have been picked from Plot 1 than from Plot 2.

J. B. R.

February 26, 1910.

BLACK-ROT AND CANKER OF CACAO.

With authors compliments

JAMES BIRCH RORER.

Trinidad
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The Relation of Black-rot of Cacao Pods to the Canker of Cacao Trees.

THE facts that cacao pods arising from cankered cushions usually become black, and in the early stages of decay are well covered with the sporophores of *Phytophthora omnivora*, the black-rot fungus; that healthy cushions frequently become cankered when the pods which they bear are attacked by this fungus; and, finally, that the fungus can be isolated in pure culture from cankered inner bark some distance from a cushion, led the writer to believe that the two diseases were caused by the same fungus. A series of inoculation experiments made with *P. omnivora*, and a number of different fungi supposed to be parasitic on cacao trees and pods has been made and the results seem to show that the greater part of the canker, here in Trinidad at least, is caused by *Phytophthora*, and that the black-rotted pods are the chief source of infection of the tree.

This species of *Phytophthora*, which has long been known to cause the black-rot of pods, grows readily in various culture media and fruits exceedingly well on sterilized potato cylinders or bits of cocoa wood or pods. Pure cultures of the fungus can be obtained by the usual bacteriological methods.

For the inoculation experiments a block of trees isolated from other cocoa trees and quite free from both black-rot and canker was selected so that the danger from outside infection was reduced to a minimum. Pods one half to three quarters grown inoculated with *Phytophthora* spores from a pure culture began to rot within a few days and at the end of a fortnight were entirely black, and covered with the sporophores of the fungus. When such pods were cut from the tree it was found that not only the cushion but the surrounding bark as well was cankered and that the fungus could be isolated from such diseased tissues. Inoculations made with the same fungus in either old or young wood invariably produced cankered areas within a very short time. When inoculations were made on a limb one or two inches above or below a pod the canker produced on the limb spread to the pod which began to rot from the stem end outward and sporophores of the fungus were found on the surface.

Up to the present time about forty inoculations with this fungus have been made every one of which has produced disease while not one of the control punctures has caused a pod to rot or the bark to become cankered.

A bulletin describing both diseases in detail, the causative fungus, and other associated fungi is in course of preparation and will be issued as soon as the illustrative plates are received from England.

JAMES BIRCH RORER,
Mycologist.

10th March, 1910.

Bull Trinidad Dept. of Agric. IX, 265. 1910

Pod-Rot, Canker, and Chupon-Wilt of Cacao caused by Phytophthora sp.

BY

JAMES BIRCH RORER.

INTRODUCTION.

THE three diseases discussed in this paper are met with on almost every cacao estate in Trinidad, and the first two have been reported from practically all countries in which cacao is grown commercially. The annual loss caused by these diseases cannot be accurately estimated. On some of the old estates many trees are so badly cankered that they are practically worthless, while an examination of the heaps of pods picked in the rainy season on the majority of estates shows that from 30 per cent. to 60 per cent. of the fruits are rotted. Then too many young pods are killed before they reach maturity so that they are not even gathered. The chupon-wilt was especially severe last year and many of the suckers left for renews were killed back and had to be removed.

Heretofore the relation of pod-rot to canker has never been clearly understood and the cause of each has been attributed to a number of different fungi, but cultural and inoculation experiments which have been carried on during the past eight months point to the fact that they are both caused by the same fungus. This is a species of Phytophthora which in 1899 was identified as *P. omnivora*, a well known parasite, but a careful examination shows that it is different from that species in some respects as will be pointed out farther on in this paper.

The chupon-wilt is described here for the first time.

HISTORY OF POD-ROT AND CANKER.

From the wide distribution of pod-rot and canker it is evident that these diseases have been prevalent in cacao growing countries for many years, so that their origin cannot be traced. They were reported almost simultaneously from the East and the West, but only after the yield had already been appreciably diminished on account of their ravages.

Perhaps the first reference to canker is that of Porter [1] * in his book on tropical agriculture published in 1833 in which he says: "Cacao trees are subject to a disease which shows itself in the form

* The numbers refer to the Bibliography which will be found at the end of the paper.

of black spots, or blotches, on the bark, and which as soon as they appear should be carefully cut out or the tree will quickly die. This disease does not make its appearance until the trees are in a bearing state."

Another early reference to a cacao disease which may have been the Phytophthora pod-rot, is that of Dr. de Verteuil [2] in his book on Trinidad. He says: "In the year 1727, however, a terrible epidemic spread in the cacao plantations of Trinidad. The trees were apparently healthy and vigorous; the flowering abundant, giving fruits, but none of them came to maturity, as the young pods dried up before full growth." As a result of this outbreak the commerce of the Island was crippled and the cacao industry was not revived until 30 years later when the Capuchin Fathers imported the Forastero cacao from the mainland which was used to a great extent to replace the Criollo, the variety previously cultivated.

It is only within the last fifteen years however, that careful descriptions of the diseases have been given, curiously enough that of pod-rot coming from the West and that of canker from the East.

Harrison in 1895 [3] reported a disease from Grenada, and described it in such a way as to leave little doubt that it was the Phytophthora pod-rot, and in 1897 [4] he found that the same disease was quite common in Suriname and present to a slight extent in British Guiana. By transferring spores from the surface of affected pods to healthy pods he reproduced the disease, thereby showing its infectious nature. The remedial measures suggested were the destruction of the husks from diseased pods and the spraying of the trees with Bordeaux mixture.

At about the same time the serious nature of cacao canker was first brought to general attention because of a serious outbreak of the disease in the Matele district of Ceylon. During the early part of 1897, various letters discussing the outbreak and giving theories as to the cause of the disease appeared in the *Tropical Agriculturist* and the newspapers of Ceylon, but the first detailed description of the disease under the name of cacao canker was given by Willis and Green. [5]

These authors made a tour of the cacao districts of Ceylon and found the disease widespread. Experienced planters stated that they had observed it for at least 20 years and that it had become quite prevalent since 1892 or 1893.

Canker was found to be largely confined to the "old red" cacao (a Criollo type), while Forastero was but slightly attacked.

The disease was recognised in its earliest stages by a darkening of the surface of the bark, and as it became more pronounced a pinkish gummy matter exuded from the diseased area. The tissues beneath these diseased patches of bark were of a claret red or brownish colour, and were separated from the normal whitish or yellowish tissue by a definite cork cambium layer, visible as a dark narrow line. It was found that vigorous growing trees when attacked

might throw off the diseased patches by new growth from below, but most commonly, however, the disease worked into the cambium layer which became brown and decayed. As a rule trees in a weak condition were more frequently attacked than vigorously growing ones.

A branch immediately above a diseased patch usually died while frequently the whole top of a tree withered up as a result of the girdling of the trunk by the disease. The young branches and roots however never seemed to be attacked.

From the general character of the disease and the fact that it spread chiefly during the wet season, the authors concluded that it was of fungous origin, though no definite parasite was found in the diseased parts.

They suggested that the disease might be held in check in two ways, namely by putting the trees in better condition to withstand fungus attack by drainage and a reduction of shade and by the exercise of more care in pruning and digging out borers so as not to leave large open wounds as points of infection, and by cutting out and burning the diseased tissue, but if a stem was badly affected the advice given was to cut down and burn the whole tree and supply with Forastero.

Soon after beginning work on the disease, Willis sent material from diseased trees to Kew for examination, and asked that a specialist be sent to Ceylon to study the disease. The report upon this material by Morris and Massee together with a further note on the disease by Willis was published later in 1897. [6]

In his memorandum to Willis, Morris took for granted that the disease was one of the roots and suggested as a remedy that the estates be better drained, the shade thinned out and the soil thoroughly forked and well limed in areas where trees had died, and that healthy trees should be isolated by deep trenches and given only the amount of shade absolutely necessary.

In an examination of the material sent from Ceylon, Massee found the mycelium of a basidiomycetous fungus in the tissues and from this concluded that the disease was one of the roots rather than of the stem. He seconded Morris' remedial suggestions and in addition emphasized the necessity of digging out the roots of dead trees and sterilizing the soil by fire.

The Director of the Royal Gardens, Kew, considering that these reports left little room for doubt as to the cause of the disease thought it unnecessary that a specialist be sent out.

In his comment on the reports of Morris and Massee, Willis stated that the observations made in the field contradicted the root disease supposition, and further that, since the previous report, reproductive organs of a fungus apparently the cause of the canker had been found on the bark of diseased trees.

These organs were not found on the roots. This fungus was not identified however, but simply the statement made that it belonged to the group of fungi causing many of the bark cankers.

The recommendations given in the previous circular were repeated with the added suggestion that all diseased trees and the stems of shade trees should be sprayed with Bordeaux or lime sulphur mixture, and that it would be better perhaps not to remove the

suckers from trees on estates where the disease was bad, as the wounds offered openings for the fungus to attack the trees.

Through the action of the Ceylon Planters' Association, Carruthers went from England to Ceylon and undertook a study of the disease, devoting the whole of the year 1898 to this work. His results were published in three reports, [7], [8], and [9].

In the first report [7] Carruthers concluded that the disease was of fungous origin and attacked only the stem of the tree. He found septate fungous hyphæ in the affected tissues of the bark, and sporophores, which he considered to belong to the same fungus, on the surface of the diseased areas. Two types of spores were found, small oval, and long crescent shaped ones usually 8-septate.*

To prove that this fungus was the cause of the disease he made a number of inoculations on 5 to 7 year old healthy cacao trees, using bits of diseased tissue and spores of both types taken with a paint brush directly from the sporophores found on diseased bark. Slanting cuts were made through the bark into the wood and the inoculating material put into this wound which was then bound up firmly, and wrapped with wet paddy straw to keep the inoculated areas moist.

Ten inoculations were made with bits of diseased bark, thirteen with the microconidia and six with the macroconidia while two cuts were made and wrapped with moist straw as controls. The results of the inoculations were given in a table.

The inoculations made with the bits of diseased tissues were the most successful as the disease was produced in seven cases within two or three weeks time. Four of the thirteen inoculations made with the small primary spores (microconidia) were considered successful, but none showed symptoms of disease until after the third week and two remained doubtful until the sixth week.

Only one of the inoculations made with the septate spores (macroconidia) was successful, and in this case no signs of disease were observed until after six weeks time.

The remedial measures suggested were practically the same as those given by Willis and Green in their first report namely to cut out the cankered areas and reduce the shade to the minimum necessary amount.

In this report Carruthers called attention to the serious nature of the pod-rot and ascribed it to a peronsporaceous fungus. He estimated that 50 per cent. of the crop in Ceylon was annually destroyed or rendered of inferior value by this disease. He inoculated a number of healthy pods by inserting in cuts bits of diseased pods and in every case the disease was quickly induced and the pods were entirely rotted within 8 or 10 days.

Carruthers in his second report [8] gave a detailed description of the canker disease and its effect upon the tree, the life history of the supposed causative fungus, and the methods of treatment, which after a series of various experiments, gave the best results. In addition to the two tpyes of spores mentioned in the first report, the perfect stage of the fungus in the form of small crimson spherical bodies

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*These were evidently the micro- and marco-conidia of a Fusarium though no name was given to the fungus.

containing asci and spores was found on diseased bark so that the life cycle of the fungus was completed.

Further it was found that no special predisposition of the trees was necessary for the attack of the fungus, the only conditions necessary being the moisture and heat requirements of the fungus.

The remedial measures as given in the first report were found to be successful, but the necessity of burning all diseased parts removed was further emphasized.

The remedial measures found to be of value were :—

1. To excise all diseased tissue, being careful to cut out beyond the discoloration. In cases where a tree was very badly affected the bark might simply be shaved, but this method was only to be resorted to in cases where the entire removal of the diseased tissue would likely prove fatal to the tree.
2. To burn all diseased parts so removed.

A canker was also found in the thorny Bois (*Erythrina umbrosa*) which was considered to be the same as the cacao canker because the latter could be produced by inoculations with diseased tissues and spores from the Erythrina.

Further notes on the pod-rot were also given in this report and as a remedial measure the suggestion was made to pick and burn all pods as soon as affected.

After the publication of these two reports on canker and pod-rot several Ceylon planters called attention to the fact that in many cases the bark of the tree around the cushions bearing diseased pods was cankered, and asked if there was not some relationship between the pod and the stem disease.

In his third report[9] Carruthers took up this question. Examinations led him to believe that undoubtedly there was a connection between the canker in the bark and the diseased pods. In his earlier examinations he had overlooked the fact that in addition to the spores and mycelium of the peronosporaceous fungus the mycelium and conidia spores of the canker fungus were also present on the diseased pods. In order to show the action of the canker fungus on pods he carried out the following experiments :—

"(*a*.) Pieces of cankered bark were placed in selected healthy pods on sound trees. Five pods were so treated. In all cases the pods became diseased after about eight days, and in less than fourteen days spores of both fungi were produced in abundance.

(*b*.) Pieces of diseased pods were placed in the bark of sound trees. Eight of these experiments were made. In all cases canker was produced in the bark after about ten days.

(*c*.) Pieces of cankered bark were placed in the bark of sound trees just above the stalks of healthy pods. Seven of these experiments were made. In all cases the pods became diseased, and on them were produced the spores of both fungi in about eight days, and on their stalks the spores of the canker fungus only.

(*d*.) Pieces of diseased pods were placed in healthy pods on sound trees, and the disease having been produced, the

effect on the adjoining bark was observed. Six of these experiments were made. In three of these experiments the canker was produced in the bark of the tree adjacent to the stalk, and in the other three cases the stalk of the pod was cankered, but not the adjacent bark; in one of them the canker went into the wood of the tree through the stalk, but without affecting the bark surrounding the stalk."

From these experiments the following conclusions were drawn:—

"1st. That the canker fungus can spread from the bark to the pods.

2nd. That the canker fungus can spread from the pod to the bark.

3rd. That the pod disease before described (in the first report) affecting the pod does not grow in the bark and is confined to the pod tissues not running into the stalk of the pods."

Further, Carruthers also stated that the experiments showed that the canker fungus grew much more rapidly in the pod tissue than in the bark and produced its spores much sooner on the former than on the latter. "On the bark it takes weeks and often months for the spores to form; on the pods, it is a matter of days. The prompt appearance of the Peronospora fungus after the canker has affected the pods is shown by experiment (c); but the exact share which these two fungi take in the destruction of the pod tissues should be made the subject of further experiments and observation."

An examination of some hundreds of diseased pods showed that the two fungi were in every case found associated; as the probable explanation of this it was suggested that the Peronospora fungus belonging to a group most of which are parasitic, but which also has some members which are saprophytic, at once succeeded the canker fungus and lived on the tissue killed by it. He was not able to prove this on account of the difficulty in isolating the Peronospora spores *alone* on a healthy pod. "The action of the canker spores alone was observed on a healthy pod, but in the space of about two hours they were joined by the Peronospora fungus and spores of this latter produced."

As a result of this activity in the East the subject of cacao diseases was brought before the Agricultural Society of Trinidad for attention during the year 1898. Specimens of diseased pods were submitted to Hart who reported [10] that after a careful and lengthy microscopical study he was unable to say that the pods had been destroyed by disease, but advised that a strict watch be kept for anything which appeared to be of a pernicious character.

More specimens of diseased pods were submitted to the Society a little later and early in 1899 a committee was formed for the purpose of finding out the nature of this disease and its prevalence in Trinidad.

The report of the committee [11] was as follows:—

1. The malady was due to a fungus. (Specimens had been sent to Kew for identification).
2. Experienced planters had known the disease for at least twenty-five years.

3. There was no evidence to show that the cacao tree itself was in any way affected by the disease of the pods.
4. Experiments made by the Government Botanist showed that the disease could be transmitted from one pod to another by inoculation.
5. The disease was more common near the breaking places than in other parts of estates.

To combat the disease it was recommended to cover all refuse with soil and bury it and to collect and destroy all pods which showed signs of the disease. In conclusion the Committee thought that the importance of the disease in Trinidad had been over-estimated.

Massee [12] reported on the material which had been sent to Kew for examination. He identified the fungus causing the trouble as *Phytophthora omnivora* De B., and found that the oospores were formed in the pod tissues. He also found on the surface of the diseased pods another fungus which he named *Nectria bainii* and suggested that this fungus might possibly attack the trunk of the tree.

Hart [13 14] was the first to make pure cultures of this Phytophthora and with them to reproduce the disease by inoculation.

A disease of the cacao tree itself similar to the anker in Ceylon was evidently first noted in the West Indies during the year 1899. Specimens were sent to the Trinidad Botanical Department by a planter and were then forwarded to Kew for examination. On this material Massee [15] found a Fusarium and a Nectria and stated that the symptoms of the disease appeared to be identical with those of the canker disease of Ceylon, but he could not say whether the species of Nectria associated with the diseases in the West and East respectively were the same, as that from Ceylon had not yet been described in detail.

It was not until the latter part of 1900 that Carruthers [16] named the fungus which he had found associated with the Ceylon canker. He considered it to be *Nectria ditissima* Tul.

On returning to Ceylon in 1901 Carruthers [17] again took up the study of canker and pod-rot. His conclusions at this time were much the same as those previously reported. He considered that Nectria was the cause of the pod disease, and the associated Phytophthora a mere concomitant. At this time the canker had much decreased since 1898 owing to the means having been taken to combat it, and the fact that no season specially favourable to the fungus had occurred.

Howard [18] made the first full report on cacao diseases in the West Indies. He found that canker was quite common in several of the islands, but that the Phytophthora pod-rot was rarely met with outside of Trinidad. He considered that the serious pod disease which he found in Grenada, St. Lucia, St. Vincent and Dominica, was caused by *Diplodia cacaoicola* P. Henn.

In connection with the canker he found two distinct fungi on the diseased areas, sometimes one alone, at other times the two together. Specimens of these fungi were sent to Massee who regarded them as new

species to which he gave the names *Nectria theobromæ* and *Calonectria flavida.**

Howard made preliminary infection experiments by introducing ripe ascospores of each fungus (taken evidently from perithecia on diseased bark) into wounds in cacao trees; distinct infections were produced but the author stated that the matter needed much further investigation.

In 1904 Hemple [19] reported a new species of fungus, *Calonectria bahiensis* as the cause of canker in Brazil but made no inoculations with pure cultures.

Busse [20] who visited the cacao plantation in the Cameroons reported the pod-rot caused by Phytophthora as the most serious disease met with there, and for the first time recorded the occurrence of this fungus on the bark of the cacao tree, but gave no account of canker.

Lewton-Brain [21] and Stockdale [22] [28] have both within recent years reported on cacao diseases in the West Indies, but have added nothing new in regard to either canker or pod-rot.

Petch [28] in Ceylon was the first to question the parasitism of the various Nectrias and Calonectrias to which cacao canker has been ascribed in various countries. In his report he summarises the condition in Ceylon as follows:—

"(1.) A disease attacking the pod may work through the peduncle into the stem.

(2.) The stem may become diseased quite independently of any pod disease.

(3.) The first fact has led to the belief that the stem and pod diseases are identical, both being due to a Nectria.

(4.) The fungi on diseased pods are Phytophthora sp. and *Collectotrichum incarnatum* always; rarely a Diplodia, and a Dialonectria not identical with any species enumerated above. This Nectria also occurs on Panex killed by Rosellinia.

(5.) The Nectria on the stem is not the same as the Nectria on the pods. The former agrees with *Nectria striatospora* Zimm. It is perhaps the commonest Ceylon Nectria, and has been found on tea killed by *Massaria theicola*, tea with branch canker, felled Albizzia, dead *Derris dalbergioides*, &c.

There are numerous examples collected by Thwaites in the Herbarium, but they have been named by Berkeley either *N. cinnabarina* or *N. sanguinea*.

(6.) If a pod is left until the disease extends through the peduncle to the bark (only a matter of one or two days), and the top of the pod, the peduncle and the surrounding bark are then cut off separately and placed in sterile chambers, Phytophthora sporangia form on all three. I have not, however, been able to obtain Phytophthora from bark in which canker has risen independently of the pod disease.

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* *N. theobromæ* was described in Bulletin Miscellaneous Information Royal Gardens, Kew, No. 5. p. 218, 1908, but so far as the writer knows *C. flavida* has not yet been described. The spore measurements are given by Howard.

(7.) If the stem and pod diseases are the same, they cannot be due to Nectria. That both can be caused by Phytophthora seems at present improbable. In the initial stages of stem canker it is often impossible to find any hyphæ in the diseased bark ; bacteria have been found in the cases in which they have been looked for, and it seems probable that the cause of both cacao Canker and Hevea canker must be sought in this direction."

Barrett during the latter half of the year 1907 visited Trinidad for the purpose of studying plant diseases. The results of his investigations in regard to cacao troubles were given in several reports [24, 25, 26 and 27]. He estimated that from 50 to 75 per cent. of the cacao fruits were destroyed by fungous pests and 90 per cent. of this damage he estimated was due to a species of Lasiodiplodia. He found Phytophthora spores on pods but did not consider it responsible for much damage.

He considered Lasiodiplodia the chief cause of canker, but suggested also that two or three species of Nectria, as well as Phytoph thora, might gain an entrance into the bark and wood through wounds.

Although Busse did not observe canker in the Cameroons in 1903, Von Faber [29] later reported it as prevalent there. He found a species of Nectria in connection with it. He made no inoculation experiments however.

Canker on cacao in Suriname has recently been studied by Van Hall de Jonge [30]. Her work lead her to the conclusion that the disease was caused by a new species of fungus, *Spicaria colorans*, perhaps the imperfect form of a Nectria. This fungus was isolated by cutting out bits of wood and bark just at the advancing margin of the disease and transferring them to sterile culture medium in tubes or petri dishes. In addition to the Spicaria stage the fungus had a Fusarium stage. The Fusarim macroconidia were found to be different from those of the common Nectria on cankered wood which she considered *N. striatospora* Zimm. Mrs. Van Hall was unable to reproduce the disease by inoculation either with bits of diseased bark or with spores from her pure cultures.

Last year Von Faber [31] published a lengthy monograph on cacao diseases occurring in the Dutch Colonies. The writer has not yet seen this paper but from a short review which he has read it is evident that Von Faber considers several species of Nectria as the cause of canker.

The writer [32] recently published a short note stating that canker in the tree could be produced by inoculation with Phytophthora, and that this fungus had been isolated from cankered bark some distance from a cushion.

From a study of the literature dealing with the pod-rot and the canker of cacao as outlined in the preceding pages, the following facts become apparent :—

1. A serious disease of cacao pods called either black-rot or brown-rot has been known in all cacao growing countries for the past fifteen years or more.

2. It has been proved by inoculation experiments with pure cultures that this disease is caused by a species of Phytophthora generally considered *P. omnivora* De B.
3. A disease of the cacao tree to which the name canker has been applied is also found in practically all cacao growing countries.
4. The descriptions of this disease which have been given leave little doubt that it is the same in all places.
5. A large number of different fungi, mostly belonging to the Nectria group, has been reported as the cause of this disease.
6. Canker has never been reproduced by inoculation with pure cultures of any fungus (with the exception of the writer's experiments), in fact the results were negative in the only instance in which pure cultures of the supposed causitive fungus were used.
7. The disease has only been produced artificially by inserting in wounds made in healthy trees, bits of diseased bark or pod, or spores of species of Fusarium, Nectria, or Calonectria taken directly from the surface of diseased bark.
8. A number of investigators have observed that the cushions bearing diseased pods frequently become infected, and *vice versâ* that pods frequently become infected from diseased cushions, but whether the same fungus caused both diseases has never been clearly shown.
9. For the control of the pod disease the gathering and burning of all diseased pods, and spraying has been recommended generally, while for the control of canker excision and burning of diseased patches and spraying are the remedies given.

Description of the Diseases.

The pod-rot and canker of cacao have been so frequently described and are met with so commonly on every estate that they are quite familiar to all who are acquainted with cacao cultivation. The common names which have been applied to these diseases however are somewhat misleading. The pod-rot caused by Phytophthora is generally known in the West Indies as black-rot, while in the East it is called brown-rot a name applied in the West to a different disease caused by *Diplodia cacaoicola*. To avoid confusion the writer would suggest that it be called simply pod-rot or perhaps better Phytophthora pod-rot. Moreover the names either black-rot or brown-rot are misleading for the rotted pods may be either brown or black in colour according to the age of the pod and stage of the disease.

Although the term canker is somewhat of a misnomer for the bark disease yet it is in such general use that it is retained in this paper. The term chupon-wilt has been applied to a disease described here for the first time which was met with frequently last year on a number of different estates.

Phytophthora Pod-Rot.

This disease may attack pods of any age from the very small chirellos to the mature pods ready for picking. The fungus causing it can gain entrance through the unbroken epidermis so that surface

wounds are not necessary for infection. On the small pods the point of first attack becomes evident as a small black dot which may be anywhere on the surface of the pod. The fungus once within the tissues grows very rapidly so that the whole pod becomes black, shrivelled, and dry within 24 or 48 hours. The rapid withering and drying of these pods frequently kill the fungus before it has time to produce any spores.

Later on these dead pods becomes covered with the mycelium and sporophores of various saprophytic fungi. (Plate X, fig. 4.)

It must not be understood that the death of all small pods is due to this disease, but as will be shown later undoubtedly an appreciable percentage of small fruits are lost each year on account of fungus attack.

The first evidence of the disease on the large pods, half to full grown, is a slight brownish discolouration about the points of infection, which may be anywhere on the surface of the pods but are generally at the tip or stem end. (Plate X, figs. 1 and 2.) The disease spreads very rapidly in all directions from the point of first attack. On the surface of the pod the line of demarcation between the healthy and diseased tissue is quite distinct, but in the fleshy tissues beneath the epidermis there is no such line and the disease will be found to be an inch or more in advance of the line showing on the surface. The whole pod becomes brown within the course of a few days and white powdery masses of spores begin to appear on the surface, especially along the furrows. (Plate X, fig. 3.) If the pod is not yet full grown and the seeds are still closely appressed to the inner surface of the husk the fungous mycelium soon penetrates the beans and destroys them. If the pod is almost ripe when first attacked and the seed mass is free from the inner wall the seeds may not become affected for some time. Numerous saprophytic fungi quickly follow up the disease and the whole pod eventually rots away if the weather is damp, otherwise it becomes black and shrivelled and may hang to the tree for some time. (Plate XI, figs. 1 and 2.) The rapidity with which the disease progresses can be realized when it is borne in mind that though most estates are picked over on the average of once every month or six weeks, and all pods showing disease are cut down, at each picking, especially in the rainy season, a goodly percentage of fruits show the disease in its last stages.

Canker.

Trees which are badly attacked by canker can readily be picked out by their general sickly appearance evidenced by dead branches, large numbers of black pods, chupons dying from the base upward and the lack of foliage, but by an examination of the bark superficially it is often difficult to locate the cankered areas unless they have reached the bleeding stage. The only sure method of locating canker in trees is by means of the diseased pods during crop season. If a half or full grown pod is seen rotting from the stem end outward it is almost always a sure sign that there is canker in the tree. When such a pod is cut off it will be found either that the cushion and a large surrounding area of bark is cankered or that fine strands of diseased tissue lead up or down to areas of canker.

When the outer bark is cut off from the cankered regions the diseased tissue below is found to be a claret colour and is generally surrounded by a dark line of cork cambium which separates it from the surrounding light yellow or pinkish healthy tissues. (Plate IX, fig. 1, and Plate XV, fig. 2.)

The extent of cankered area however can never be judged by the area that is diseased near the surface of the bark for deeper cuts show that the disease spreads chiefly in the innermost layers of the bark, in the cambium or even in the outer layers of the wood. When trees become badly diseased a thick reddish fluid is exuded from natural cracks or holes made by boring insects in the bark covering the cankered area. This liquid runs down the trunk giving the trees a rusty appearance.

Chupon-Wilt.

This disease was very prevalent on many estates last year. The chupon is generally first attacked in the soft tissue near the tip. A small water soaked area can be seen on the stem which gradually becomes sunken and darker in color and spreads up and down the stem frequently girdling the shoot and causing the upper part to wilt. The same disease has been observed on young shoots on the upper branches of the tree. The point of attack is generally in the axil of a leaf, though the leaf blade or petiole may be the first part affected, the disease afterwards running down into the stem.

Chupons are also frequently killed by aphides or other sucking insects, and such cases should not be mistaken for the disease of fungous origin. The final appearances of the killed shoots are the same but the initial stages are quite different.

Losses caused by these Diseases in Trinidad.

It is impossible to estimate exactly the losses caused by these diseases in Trinidad. In some of the older estates of the Island at least one quarter of the original trees have been killed out by canker while the bearing capacity of the remaining trees, the majority of which are more or less diseased, is greatly lessened. On many estates during the rainy season from 40 to 50 per cent. of the pods which are picked are rotted. The beans from the worst affected pods are of no value whatever and become entirely lost in either the fermentation or dancing process while those from the less severely attacked pods are always light in weight and easily broken. Moreover a large number of chirellos are killed which can only be roughly estimated at 10 to 15 per tree per year.

The chupon-wilt frequently makes it impossible to grow renews. Taking all things into consideration it is conservative to estimate that the out-put of cacao of the island would be from 40 to 50 per cent. more if these diseases were not present.

Cause of the Diseases.

The cause of the pod-rot, canker, and chupon-wilt is a fungus belonging to the genus Phytophthora which has been generally considered *P. omnivora*, but some of its characters are different from those of that fungus, and studies which are being carried on may show it to be autonomous. A description of the fungus follows :—

Cacao Phytophthora.

Conidiaphores break through the epidermis or stomata in dense masses, are long and generally unbranched, becoming decumbent and forming a rather dense hyphal network on the surface. Conidia are formed at the ends of the sporophores. When a spore is about half grown the growth of the sporophore is continued by a branch, arising immediately beneath the spore, which in turn forms a spore, at its tip. Spore formation continues as long as favourable growth conditions exist. There is no swelling of sporophores below conidia. Conidia vary in shape from narrow to broad ovate and in size from 30–60 × 21–30 microns but are usually 30–50 × 25–27 microns, and have a prominent germinal papilla. Spore wall is thin, smooth and colourless. Contents granular and colourless. The spores germinate either by emitting from 15 to 30 biciliate zoospores or with one or more germ tubes. Chlamydospores abundant 30–50 microns in diameter. Oospores are spherical, 33–40 microns in diameter, with colourless, thick, smooth wall and granular contents. Are formed on the surface and within the tissues.

This fungus differs from the European type of *P. omnivora* in its longer sporophores, smaller conidia, and larger oospores.*

Sources of Infection.

Diseased pods are undoubtedly the chief souree of infection for all these diseases. During the rainy season spores are produced in enormous quantities on the surface of diseased pods. These spores may be blown by wind, washed by rain or carried by insects to other pods where they quickly germinate, and reproduce the disease. From the fact that there are always pods on the tree the disease is kept going month after month and year after year. In addition to the spores borne on the surface of the pods the resting spores which are formed within the rotted tissues also aid in the distribution of the disease and can tide the fungus over long periods of drought or other unfavourable conditions.

Though canker may get into the trees through wounds made by the goulette or cutlass the diseased pods are unquestionably the chief source of infection of the tree.

Hundreds of cushions bearing pods which had rotted from the point to the stem have been examined and found cankered. The disease at times affects the whole cushion, but often is observed only as a few discolored strands, which however can be traced up or down the stem and sooner or later spread out into large canker patches. Chupons readily become infected from spores which are carried by rain or insects from diseased pods.

Other Fungi associated with the Diseases.

In addition to Phytophthora a number of other fungi are nearly always found associated with pod-rot and canker. As many of these

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* Through the kindness of Professor H. H. Whetzel of Cornell University in sending the writer cultures of the American form of *P. omnivora* cross inoculations are being made with the two fungi. Professor Whetzel has also kindly consented to test the cacao fungus on ginseng. The result of this work together with an examination of European material will make it possible to establish the identity of the cacao fungus.

have been reported as parasites, and considered the cause of pod-rots and canker as complete a collection of them as possible was made. On diseased pods in addition to the Phytophthora, at least three different species of Fusarium were found as well as several Nectrias, a Calonectria and two species of Sphærostilbe. On cankered bark two species of Fusarium have nearly always been found, two Nectrias, two Calonectrias and two species of Sphærostilbe. These fungi have been identified as far as possible. The commonest Nectria found on both pods and bark is *Nectria theobromæ* which Massee described originally from material sent to Kew from Grenada by Howard. Mrs. Van Hall reports and figures the same fungus from Suriname. This fungus is not *Nectria striatospora* Zimm. The latter is the common Ceylon Nectria to which the canker there was ascribed first by Carruthers. The ascospores of this species are smaller than those of N. *theobromæ* and the conidia spores of the Fusarium type are also much smaller. Another Nectria frequently found on diseased pods is *N. bainii* Massee. A Calonectria which has not yet been determined has also been found on pods as well as an undetermined Nectria with very small spores. On the bark in addition to *N. theobromæ*, *Calonectria flavida*, an undetermined Spharostilbe and *Spicaria colorans*, have been frequently found.

Cultural Studies.

Single spore cultures of all these fungi have been made. In making these cultures the method advocated by Dr. Erwin Smith has been used. In the case of the Nectrias, Calonectrias and Spærostilbes single perithecia were picked off with a sterile needle, mashed up in a drop of sterile water which was then put into a tube of melted agar and poured out into a petri dish. When the agar became hard the dish was turned upside down and a search for the spores made under the microscope with a medium power lens. The position of several isolated spores was marked on the bottom of the dish. These spores were then cut out and transferred to sterile agar in petri dishes and their growth watched under the microscope, and transfers were made later to tubes. Pure cultures of the Fusariums and Phytophthora were obtained by the ordinary poured plate method.

In addition to the cultures made from spores found on the surface of the diseased pods and bark, cultures were made directly from the diseased tissues themselves. Pods in which the rot had just started were selected for this work. They were washed thoroughly with water and then soaked in a solution of mercuric chloride 1·1000 for 10 minutes. Then with a hot knife a slice was quickly cut off along the advancing margin of the disease. With a cold sterile knife small bits of the diseased inner tissues were cut out and immediately transferred to sterile media in tests tubes. Cultures were made from cankered limbs and branches in the same way as well as from the wilted chupons.

Cultures made by this method from diseased pods and wilted chupons have invariably given a pure growth of Phytophthora, but those from cankered wood have generally given a variety of different fungi. In some cases pure cultures of Phytophthora were obtained but often *Nectria theobromæ* and *Spicaria colorans* were got, and rarely *Diplodia cacaoicola.*

During the past year 275 cultures have been made of the fungi associated with canker.

Life History of Cacao Phytophthora.

So far as the writer has observed this fungus passes its whole life history in parts of the cacao tree or fruit. The fungus produces conidia spores abundantly on diseased pods, and rarely on diseased bark. (Plate XVII, figs. 1 and 2.) If placed in water these spores germinate within 30 minutes by letting out from 10 to 30 small zoospores which after swimming about for a variable length of time, generally about 10 to 15 minutes lose their cilia, or organs of locomotion, becomes spherical and within an hour will send out a germ tube. (Plate XVII, figs. 3, 4, 5, 6, 7 and 8.) If the spore has germinated in a drop of water on a cacao pod the small germ tube soon gains entrance to the inner tissues of the pod either by penetrating the epidermis or making its way in through a stoma. Once within the pod the fungus grows very rapidly absorbing food from cells and spreading throughout the tissues causing the characteristic brown discoloration. The mycelium is rather coarse and non-septate and of varying thickness, being in some places rather narrow while in others quite swollen. (Plate XVII, fig. 1.)

If the large spores fall on a damp surface rather than in water they will not form zoospores, but will germinate by means of one or more germ tubes which may either enter the pod directly or produce other spores on the surface of the pod, which in turn will germinate either by forming zoospores or germ tubes.—(Plate XVII, fig. 9, 10 and 11.)

After a few days' growth within the pod the mycelium begins to mass up at points just beneath the epidermal layers of cells, frequently in the substomatic chambers. The pressure of this mass of mycelium finally ruptures the epidermis and rather slender hyphae grow out through the opening so formed The tips of these hyphae soon begin to swell, and finally become the characteristic lemon-shaped spores When the spore is about half grown the sporophore sends out from a point just below the spore a branch which in turn will form a spore at its tip.—(Plate XVII, fig. 1.) This spore production from a single original sporophore goes on as long as nourishment is supplied and weather conditions are favourable. With the continued growth of these sporophores a rather dense fungal network is formed on the surface of the pod. Underneath this mycelial mass two other kinds of spores are found. The first are formed much as are the conidia already described, but are spherical, and so far as has been observed always germinate with germ tubes. They are quite variable in size and probably belong to the type of spores known as chlamydospores. Oospores are also formed in the net work of mycelium on the surface of the pod.

Almost simultaneously with this superficial spore production oospores are formed within the tissues of the pod, especially in the soft layer of tissue between the hard inner pod wall and the epidermis. (Plate XVII, figs. 12, 13, and 14.) These oospores serve as resting spores and may retain their vitality for a long time and carry the fungus over long periods of unfavourable conditions. The oospores

are set free by the decay of the pods and germinate with a short germ tube which forms a spore of the ordinary type at its tip.

When the tissues of the pod at the stem end have become well invaded by the fungus, the mycelium runs back into the cushion either through the bark or the central woody cylinder of the stem of the pod, or through both. If it has gained entrance to the tree through the thin bark layer of the pod stem it generally spreads out in all directions so that the whole cushion and surrounding area of bark becomes cankered (Plate IX, fig. 2, and Plate XV, fig. 2) ; but on the other hand if the mycelium grows into the tree through the woody part of the pod stem the cushion may not become cankered. The mycelium will extend in narrow lines for some distance up or down the stem in the cambium layer but sooner or later will grow outward into the bark and then spread out rapidly forming larger cankered areas. (Plate IX, fig. 1, and Plate XV, fig. 1.)

As the tissues of both pod and bark are killed by the advancing margin of growth of the Phytophthora mycelium they are quickly invaded by a number of rapidly growing fungi as mentioned above which produce spores very quickly on the diseased tissue. There can be no question that these fungi aid in the rapid disintegration of the already diseased pod tissues and are responsible to a certain extent for the characteristic appearance of cankered bark, but that they are not parasitic and cannot even attack tissues which have been wounded mechanically has been proved by a larger number of inoculation experiments.

Inoculation Experiments.

Considering the fact that cacao canker has been ascribed to a number of different fungi, though the characters of the disease have always been much the same, and that great difference of opinion has existed as to the relation of canker and pod disease, a series of inoculation experiments was started in the latter part of 1909 with the hope that some of the doubtful points might be cleared up. By the method described previously pure cultures, originating from single spores, of a number of different fungi associated with pod-rot and canker were obtained. These strains have been kept pure and all inoculations have been made from them. Before field inoculations were begun preliminary tests were made with the different fungi on half to full grown pods kept in moist chambers in the laboratory. The surface of the pods was thoroughly washed in tap water, then in sterile distilled water. One set of pods was inoculated by inserting the fungus spores from the cultures in small wounds made with a sterile bistoury and another set by simply placing the spores in drops of water on the unbroken epidermis.

The following fungi were used :—*Phytophthora omnivora* (?), *Diplodia cacaoicola*, *Nectria theobromæ*, *N. bainii*, two species of Calonectria one of which is doubtless *C. flavida*, two species of Sphaerostilbe, neither of which has yet been determined and *Spicaria colorans*. After inoculation the pods were examined daily for a month. The pods inoculated in wounds with Phytophthora and Diplodia began to rot very quickly and were completely rotted within ten days. The pods inoculated with Phytophthora spores simply put on surface rotted almost as quickly, but those inoculated with Diplodia

in this way rotted much more slowly. None of the pods inoculated with the other fungi rotted, even in the cases where punctures were made; the tissues remained sound and there was only a slight discoloration immediately about the puncture The field inoculations were made on a block of cacao trees of different varieties well isolated from other cacao trees. The trees were free from canker and the pod disease. In all over 150 inoculations have been made with the different fungi, and have generally been made in series so that the conditions for each fungus would be the same; in all cases checks have been made.

Inoculations were made in two ways, in the first the bark of the tree or epidermis of the pod was wounded and the inoculating material put into the wounds, in the second the spores were suspended in water which was sprayed on the bark or pods with an atomizer. In the majority of cases where wound inoculations were made on suckers, limbs or trunks of trees the inoculated area was covered with a layer of surgical gauze and then wrapped with grafting tape in order to keep the wounds from drying out too quickly, but no attempt was made to keep the wounds moist artificially and the wrappings were always removed after 7 to 10 days. Too much space would be required to give the whole list of inoculations and little would be gained as in many cases it would be simply repetition so that only some of the most striking ones will be given in detail. In all cases in order that there might be no doubt that there were spores in the cultures used for inoculation microscopic preparations were made and examined just before the inoculations were made, and to show that the spores were active transfers were made from each tube to fresh sterile agar in tubes.

As it was quite unlikely that all the species of Nectria, Sphaerostilbe, Calonectria, etc., which had been isolated from diseased pods and bark were parasitic a set of inoculations was made in January for the purpose of weeding out the saprophytes. Vigorous growing trees of from 3 to 4 inches in diameter were selected for the work. The inoculations with each fungus were made in exactly the same manner, namely, with a sterile knife a small cut about ½ inch long was made in the bark and with a sterile platinum needle spores were transferred from the pure cultures to the cuts. The wounds were then immediately bound up as described above. (The surgical gauze was used simply to keep the tape from sticking to the bark). At this time eight inoculations were made with Phytophthora, five with *Nectria theobromæ*, five with *Spicaria colorans*, five with *Diplodia cacaoicola*, and three with each of the other fungi mentioned. Five cuts were made and wrapped in a similar fashion to serve as checks.

The wrappings were taken off from all the inoculations and checks after 8 days. Even in this short time there was evidence that the inoculations made with Phytophthora were taking effect. The following notes were made:—"I think that there is no question that "the fungus is working. Within a radius of from one to two inches "about the points of inoculation the bark is darker than normal, and "when a very thin layer is cut off the tissues below are darker there "than they should be and have a water soaked appearance."

The inoculations made with all other fungi, with the exception of those in which Diplodia was used, appeared in no way different from the check wounds except that in some cases there was a slight fungous growth just in the margin of the cuts. When thin layers of bark were cut off however the tissues beneath were perfectly healthy.

An exactly similar set of inoculations were made on February 11 and gave exactly the same results. In every case in which Phytophthora was used a disease in the bark was produced while the inoculations with all other fungi except Diplodia remained the same as the checks.

In all between 80 and 90 inoculations have been made in the bark of trees and the results from all have been uniformly the same, none of the fungi used except Phytophthora and Diplodia have proved to be parasitic even in the slightest degree.

The only conclusions which can be drawn from these experiments are that *Nectria theobromæ*, *N. bainii*, *Calonectria flavida* and *Spicaria colorans* when grown in pure culture and inoculated in fresh wounds in healthy cacao trees are incapable of attacking the healthy tissues and producing disease; that both *Phytophthora omnivora* (?) and *Diplodia cacaoicola* attack healthy tissues and produce disease when inoculated into wounds in cacao trees. Whether the disease caused by either of these fungi was canker remained to be settled. Though Diplodia is undoubtedly a wound parasite the disease which it produces is very evidently not the common canker. This fungus grows into the wood and attacks it at first rather than the bark, so that the whole stem becomes blackened through and through and the bark becomes brown and dry and does not assume the neutral tint or claret colour characteristic of canker. The writer's experiments with this fungus agree closely with those reported by Howard. [18]

The disease produced by inoculations with Phytophtora however shows the characteristics of canker. The fungus spreads rapidly in all directions in the bark and the attacked tissues at first assume the "neutral" tint and later on become claret coloured, and are generally surrounded by a dark line of cork cambium. (Plate IX, Figs. 1 and 2; Plate XIII, Figs. 1 and 2; Plate XV. Figs. 1 and 2.)

The writer upon several occasions has shown specimens of the disease produced by inoculation to cacao planters who have at once diagnosed it as canker, and to Mr. Carruthers, Assistant Director of Agriculture who said that the specimens were very like the disease as it occurs in Ceylon.

The trees inoculated in February have been examined frequently up to the time of writing and not only do they show cankered areas about the point of inoculation, but other diseased patches are appearing on the tree, all of which however can be traced back to the original point of infection. In some cases however the disease has evidently died out after progressing to a certain point, and new bark is now being formed under the affected area.

To show that the disease can gain entrance to the tree through the pods a number of inoculations were made. Pods of all ages from the chirellos to the mature fruit, were inoculated with Phytophthora. Twenty-five inoculations of this kind have been made.

In every case the pod rotted quickly and in many cases where the pods were over half grown the disease ran back into the stem. With the case of the small chirellos however it was different. They all became diseased but dried up so quickly that the fungus evidently did not have an opportunity to run back into the stem. This bears out observations made in the field.

The rapidity with which the disease progressed in some of the inoculations is shown by the following notes from the writer's note book:—

"No. 11. February 10, 1910—Phytophthora. Inoculated $\frac{3}{4}$ grown pod about 2 inches from the stem end. February 19.—Pod is two-thirds rotted and Phytophthora fruiting abundantly on the surface. The somewhat darkened appearance of stem would give evidence that the disease is running back into the cushion. February 25.—Pod completely rotted and is beginning to shrivel up and become hard as the weather has been quite dry. March 12.—Cut off limb and photographed with pod attached. (Plate XI, Fig. 1.) Then cut off pod. Canker had run back in fine strands through the cushion and then spread out in the bark above and below. Photographed. (Plate XV, Fig. 1.) Specimen in alcohol."

"No. 11.5. February 10, 1910.—Phytophthora. Inoculated larger of two pods from one cushion. February 19.—Pod nearly all rotted. February 25.—Small pod rotted as well. Disease has evidently run back into cushion. March 12.—Both pods thoroughly rotted (Plate X, Fig. 4.), and canker spreading in bark about cushion."

Inoculations similar to Nos. 11 and 11.5 have been made repeatedly, and in by far the greater number of cases the disease has run back into the tree. These experiments together with a large number of field observations have led the writer to believe that the pods serve as the chief source of canker infection.

Other sets of inoculations were made to show that the disease in the tree could run out into the pods. In this case the stem was inoculated above or below a pod, or to one side or the other. A number of successful inoculations were obtained in this way. To quote from the note book again:—

"No. 10. February 11, 1910.—Phytophthora. Inoculated limb about 2 inches above a $\frac{3}{4}$ grown pod. Culture originally obtained from canker. February 19.—Took off tape. Inoculation taking effect; area about point of inoculation watery looking. February 25.—Cut off and photographed. (Plate XIV, fig. 2.) Phytophthora is fruiting abundantly on pod. White fungus in cracks of bark about point of inoculation is the Fusarium stage of *Spicaria colorans*. This shows how quickly the saprophytes follow. The stem of pod when cut through is brown and purplish just like canker. (Plate IX, fig. 3.) Tissue was reddish or purple all about both above and below cushion, photographed." (Plate VIV, fig. 3.)

"No. 9. February 11.—Phytophthora. Inoculated small limb bearing chirello. Inoculation made 2 inches below

pod and on opposite side. February 24.—Taking effect area above inoculation is sunken. March 18—Pod is shrivelled and partially blackened. Limb has been girdled by canker." (Plate XIV, fig. 1.)

In addition to Phytophthora the other fungi were all inoculated into pods, but none save Diplodia made any growth, all others remained like the checks. Mature pods when wounded and inoculated with Diplodia rotted but the disease did not run back into the stem so far as observed.

The results of the experiments in which the spores of the fungi were suspended in water and sprayed on the fruits and bark with an atomizer were all negative save where Phytophthora spores were sprayed on pods and young shoots during a period of wet weather. In these cases as was to be expected the fungus gained entrance to the tissues and caused disease, but whether Phytophthora hyphæ can penetrate the outer bark of older limbs has not yet been determined.

Conclusions.

Field observations made on many estates in Trinidad, and cultural and inoculation experiments as described have led the writer to conclusions at variance with those held by other investigators who have studied canker and pod-rot of cacao. There can be no doubt that the rot of the pods and canker are the two most serious diseases of cacao in Trinidad. That a species of Phytopthora was the cause of the former has been known for some time, and proved by inoculations. Moreover this fungus belongs to a group of fungi well known to be parasitic. Potato blight, and the downey mildew of the lima bean, grape, cucumber, and onion, as well as the damping off disease of a number of plants are all caused by closely allied fungi.

Although a number of different fungi all belonging to the genus Nectria or nearly related genera has been considered the cause of canker, their parasitism has never been proved by inoculation experiments with pure cultures. Inoculations made by using bits of diseased bark or pods, and spores taken directly from the surface of diseased material cannot be relied upon especially in the tropics and in dealing with diseases of the type in question. Mycelium of a number of different fungi could be present in the bits of diseased bark and pods and more than one kind of spore could readily be introduced into the inoculation wound, when spores are taken from sporodochia or perithecia on diseased material. The writer has thoroughly convinced himself of this point by making petri dish cultures from spores taken in such a manner.

When inoculations have been made with pure cultures of a number of these fungi the results have been uniformly negative so that *Nectria theobromæ, N. bainii, Calonectria flavida,* two undetermined species of Sphaerostilbe frequently found on cankered cacao bark, and *Spicaria colorans* can not well be considered as the cause of cacao canker, or of the cacao pod disease.

A large number of inoculation experiments made by the writer with pure cultures of *Phytophthora omnivora* (?) proves conclusively that this fungus is the cause of the common cacao pod-rot and of the

disease known as canker, and that the diseased pods serve as the chief source of infection of the tree.

Preventive Measures.

To control the pod disease two methods have generally been recommended. One is to gather and destroy all pods as soon as disease is noticed on them, and to husk "black cocoa" apart from the sound, and to burn, bury, or lime all the husks; the other, to prevent the disease by spraying.

Methods similar to the first have been frequently recommended for the control of a large number of fruit diseases, but from the fact that it is impossible to gather and destroy all the fruits of whatever kind as soon as they become diseased and that the fungi causing diseases of this type produce spores within a very short period from the time of first infection, the method is of a theoretic rather than of a practical value. It has long since been given up as a means of controlling such diseases as brown-rot of the peach, bitter-rot of the apple, black-rot of the grape, and other fruit diseases. Moreover a number of Trinidad planters who have tried this method as a means of controlling the cacao pot-rot have told the writer that though the disease was reduced to a certain extent the cost of the labour used in collecting and destroying the blackened pods was in no way compensated for by the increased returns from the general pickings, so that they gave up the method after a short trial.

When the fact is considered that in the rainy season a pod may become infected and completely rotted within a week or ten days and that within three or four days from the time of infection hundreds of thousands of spores are produced, each one of which in germinating liberates from 10 to 30 smaller spores each capable of reproducing the disease it can be readily understood how futile it is to attempt to check the disease by gathering and destroying the diseased pods.

The method of control by spraying, which has proved so successful in combatting similar diseases in temperate climates, is undoubtedly the best to use against pod-rot. Although a sufficiently large number of experiments have not been carried out either in Trinidad or elsewhere to make it possible to give the best recommendations as regards to time of spraying, mixtures to use, etc., yet the work which has already been done shows conclusively that the disease can be controlled by spraying at a reasonable cost, that is at a cost which is more than compensated for by the increased yield. Up to the present time the writer has definite results from two sets of experiments.

During the past eight months 2,125 more sound pods have been picked from 500 sprayed trees than from 500 adjacent unsprayed trees, and the sprayed trees have yielded in the total 1,608 more pods Twenty-five per cent of the cacao from the unsprayed trees has been "black" while only 9 per cent. of that from the sprayed trees has been so.

Though there has not been much "black cocoa" during the past five months yet in another experiment 2,415 more pods have been picked from 500 sprayed trees than from the same number of adjacent unsprayed trees. This increase in yield is due to the fact that the small fruits were protected from fungus attack.

The methods advocated for the control of canker have been the excision of the diseased tissues; the reduction of shade, better drainage, and the exercise of more care in picking and pruning so that the trees be not wounded unnecessarily. The object of cutting out the diseased tissue was to free the trees from disease, and the other recommendations were for the purpose of preventing reinfection by producing conditions less suitable for fungous growth. Though it has been observed that canker is less prevalent in places where trees have been sprayed, the value of spraying as a method of controlling the disease has never been fully appreciated. It becomes self-evident however when it is understood that the diseased pods are the chief source of canker infection rather than wounds of various kinds. No matter how carefully all the canker has been cut out, trees will always become reinfected if the pod disease is not controlled.

The evil effects of the needless wounding of trees with the goulette and cutlass and the results of improper pruning are so well known to every planter that the writer need say nothing on this subject. That most estates need better drainage is also a fact that needs no comment.

From a purely mycological standpoint the reduction or total removal of shade trees would greatly tend to reduce fungous growth on cacao estates, though both pod-rot and canker are widespread in Grenada, but from a practical standpoint the writer cannot give any advice on this subject as he has never been in any cacao growing country other than Trinidad.

Recommendations.

Although spraying in connection with tropical horticulture and agriculture is still in its experimental stage results which have been obtained in both Trinidad and Ceylon show that it is the most practical and successful method of controlling both pod-rot and canker of cacao, but as stated before sufficient work has not yet been done to make it possible to give the best recommendations in regard to time of spraying, best mixtures and spraying machinery. But the suggestions got from the experiments as far as they have gone are that for the best results trees should be sprayed at least four times a year the applications being made when the trees are well covered with young fruits. This will make two applications on each crop. But from the fact that the trees have cacao on at nearly all times of the year a spraying at any time would do some good. However, spraying should be avoided at the periods when the trees are in full bloom. The usual methods for cutting out canker should be followed but to make this work of value and to keep the trees healthy spraying should be resorted to

At some future time perhaps when estates are perfectly drained and cacao is grown without shade much less disease will be met with, but until that time comes both canker and pod-rot must be controlled by spraying.*

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* A Bulletin discussing spraying methods and spraying problems is in course of preparation and will be issued towards the end of the year. In this Bulletin will be given the complete results of the experiments which are being carried on, the mixtures and machinery used and the cost of application. An outline of the first experiments together with the best method of making Bordeaux mixture was given in the April number of the Bulletin.

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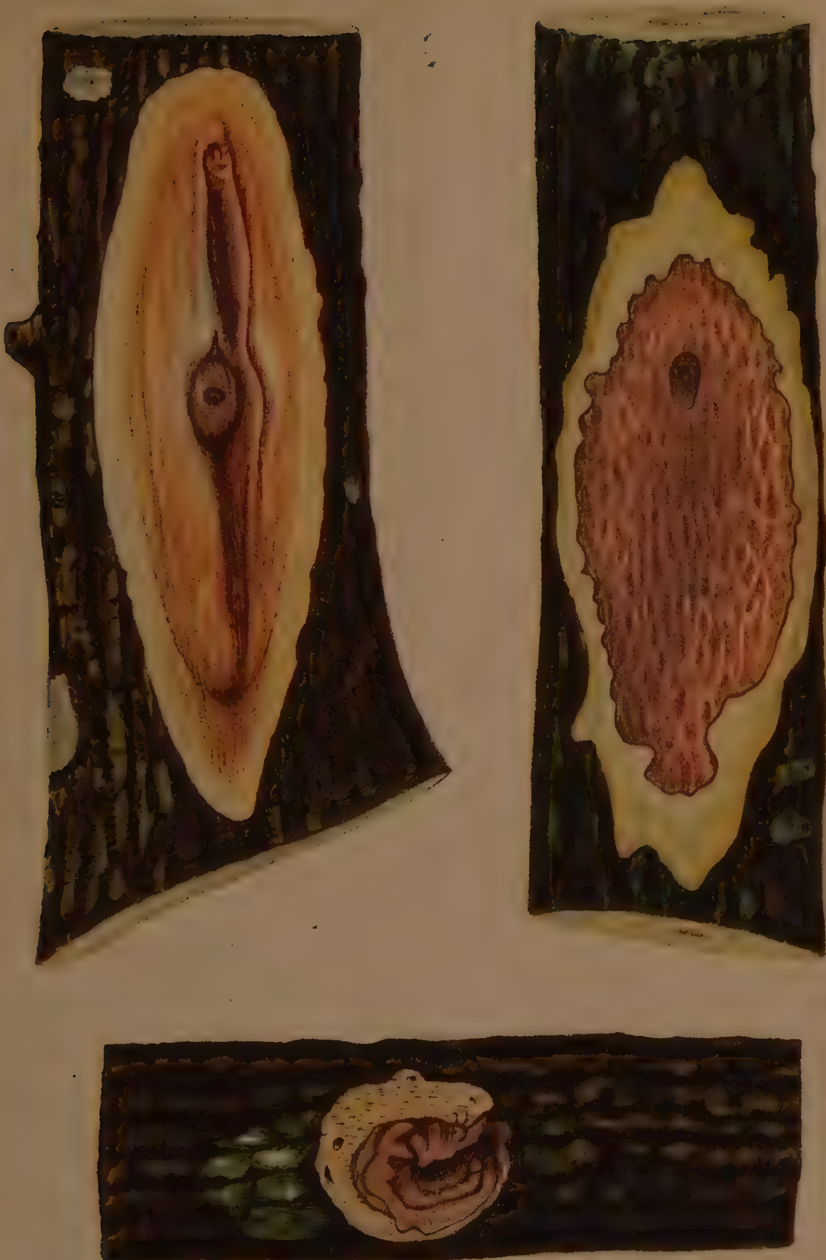
Description of Plate IX.

Cacao canker. 1.—Canker produced in stem by inoculating a pod with Phytophthora. In this case the disease did not spread to a great extent in the outer bark surrounding the cushion but extended down the stem in a narrow streak. 2.—Canker produced n stem by inoculating a pod with Phytophthora. In this case the bark surrounding the cushion was badly attacked by the disease. 3.—A cushion which has become diseased from an inoculated pod. The disease is running back both through the bark and the wood.



P. L. Guppy, Del.

A HOEN & CO BALTIMORE

CANKER IN CACAO STEMS AND CUSHIONS PRODUCED BY INOCULATION

Description of Plate X.

Fig. 1.—A cacao pod showing the Phytophthora rot just beginning at the point end. This was a natural infection. Fig. 2.—A cacao pod in which the rot began at the stem end. Fig. 3.—A cacao pod entirely rotted showing Phytophthora sporophores and mycelium on the surface. Fig. 4.—Two cacao pods entirely rotted and shrivelled. The surface is covered with saprophytic fungi. Fusarium sporodochia can be seen on the stems of both pods.

FIG. 1. A cacao pod, showing Phytophthora rot just beginning at tip.

FIG. 2. A cacao pod rotted from the stem end outward.

FIG. 3. A cacao pod completely rotted, showing Phytophthora fruiting on the surface.

FIG. 4. Two young cacao pods completely rotted.

Description of Plate XI.

Fig. 1.—A cacao pod completely rotted. In this case the rot was produced by inoculating the pod with spores from a pure culture of Phytophthora. The inoculation was made on February 11, and the photograph was taken one month later.

Fig. 2.—A pod of *Theobroma pentagona*, the alligator cacao, in which the rot was produced by inoculation. Inoculation made on April 2, and the photograph taken on April 23.

In both cases the disease had run back into the stem as is shown in Plate XV. The white masses on the surface of the pods consists of enormous quantities of spores of Phytophthora, as well as of various saprophytic fungi.

PLATE XI.

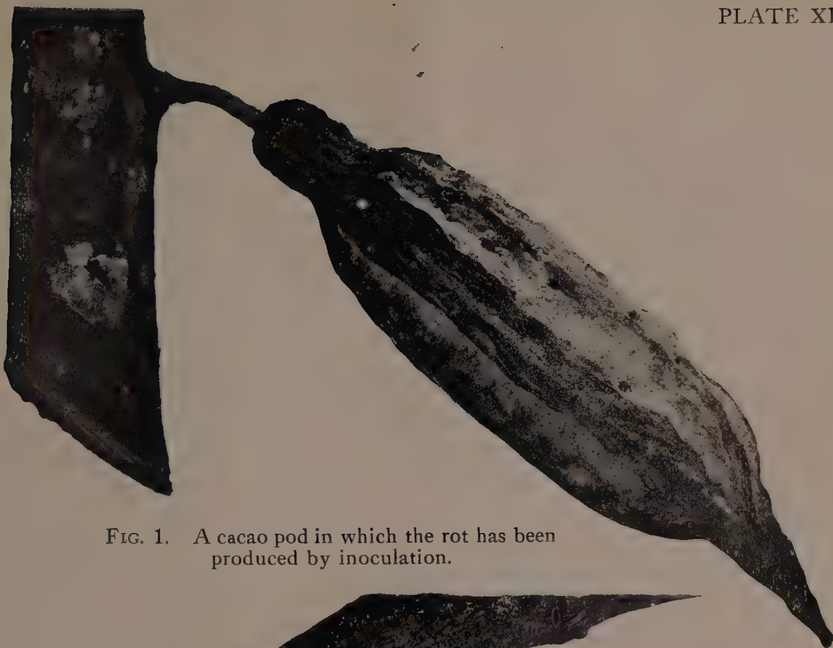
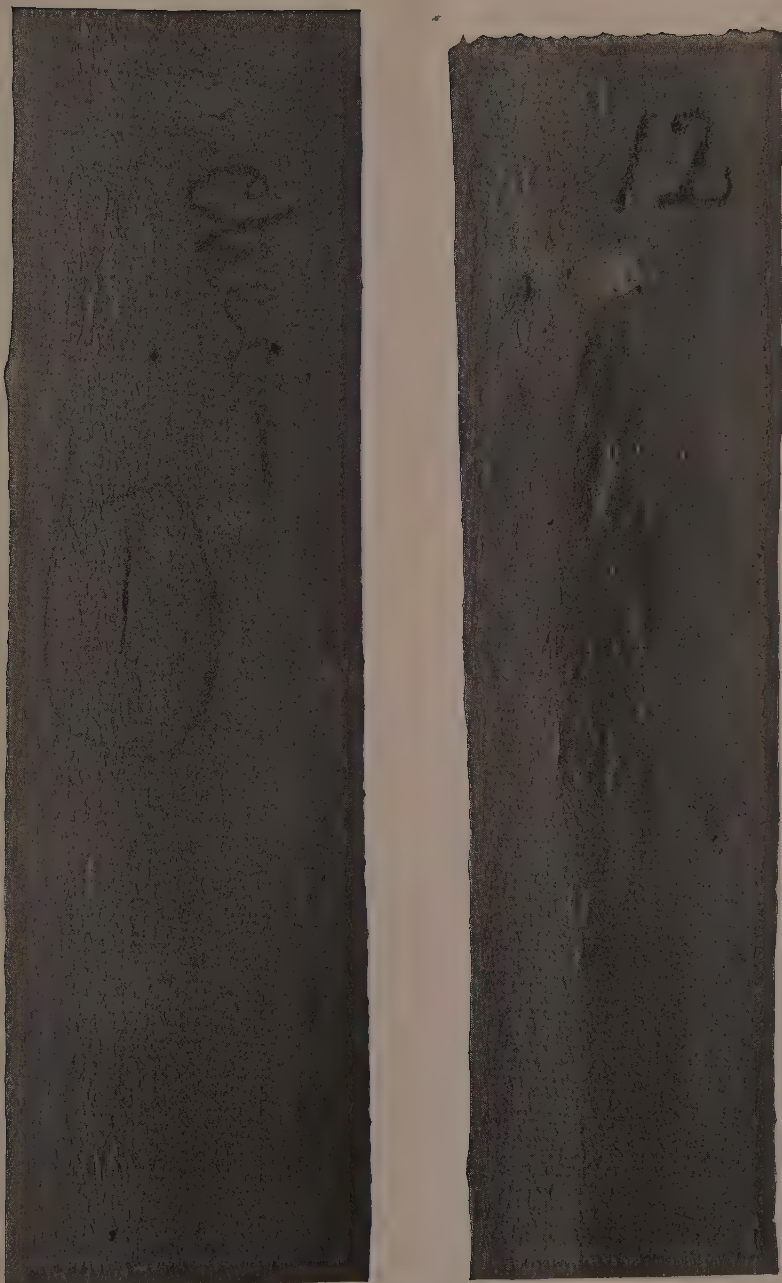


FIG. 1. A cacao pod in which the rot has been produced by inoculation.

FIG. 2. A cacao pod in which the rot has been produced by inoculation.

Description of Plate XII.

Two sections of cacao trees. The one on the right was inoculated on February 11 with a pure culture of Phytophthora obtained originally from a diseased pod. The section in the left shows check puncture made at the same time. The photograph was made on February 25. The darkened area of bark shows the effect of the inoculation. The small white pustules about the point of inoculation are sporodochia of Fusarium.



Two sections of cacao trees, one showing check puncture, the other canker produced by inoculation.

Description of Plate XIII.

INOCULATED stem shown in Plate XII with the bark cut off at different depths. In Fig 1, a very thin layer of bark was cut off. This figure shows the canker spreading almost equally in all directions from the point of inoculation. The dark line of cork cambium which usually surrounds cankered areas is noticeable here. In Fig. 2, still more bark has been cut off. This shows the canker spreading longitudinally in the layers adjacent to the cambium.

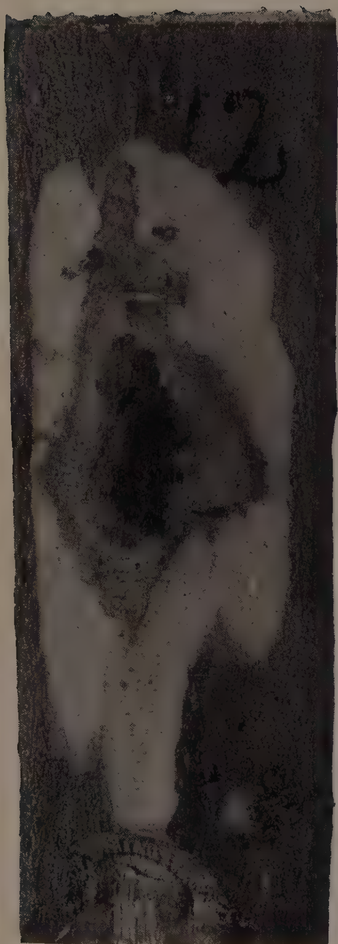


FIG. 1. Cacao stem showing canker produced by inoculation.

FIG. 2. Cacao stem showing canker produced by inoculation.

Description of Plate XIV.

FIG. 1, shows a small pod which shrivelled up and died as a result of the girdling of the stem by canker produced by inoculating the stem with Phytophthora. The point of inoculation is shown by a slight depression near the lower part of the stem on side opposite to pod. Fig. 2, shows a pod, almost full grown which became rotted as a result of an inoculation made in the tree at a point (shown by arrow). about 1½ inches above the cushion. Inoculation was made on February 11 with a pure culture of Phytophthora obtained originally from cankered bark. Photograph was taken on Feb. 25. The sporophores of Phytophthora can be seen on the diseased surface of the pod. Fig. 3, shows same stem with bark removed. Canker can be seen spreading in all directions from the point of inoculation.

FIG. 1. Black rot of pod produced by inoculating stem.

FIG. 2. Black rot of pod produced by inoculating stem.

FIG. 3. Canker in stem and cushion produced by inoculation.

Description of Plate XV.

Both figures show canker in stem produced by inoculating pods with pure cultures of Phytophthora. In Fig. 1, the arrow shows the point at which pod was attached to stem. In this case the disease ran back from the pod into the stem, but did not spread much radially but ran longitudinally for some distance. In Fig. 2, the disease spread radially about the cushion in the outer bark.

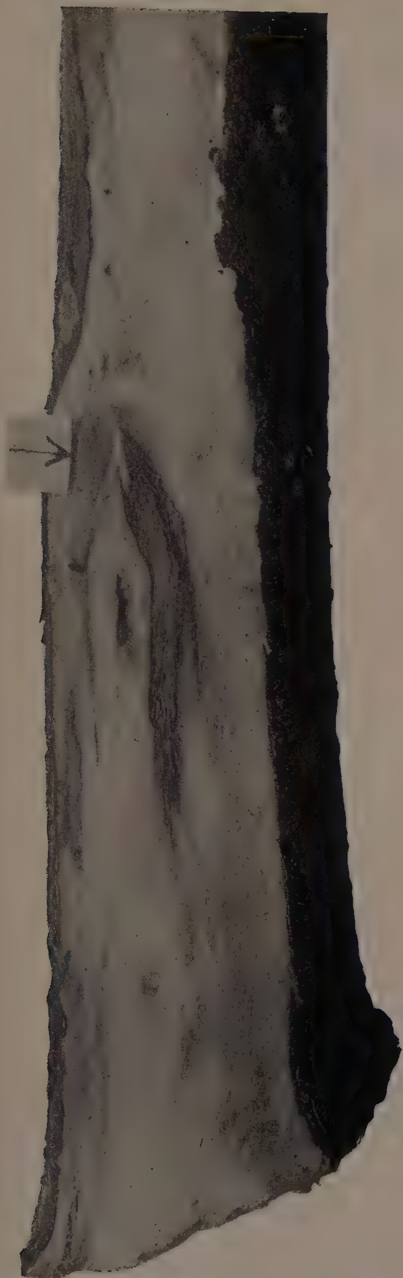


FIG. 1. Canker in stem produced by inoculating a pod.

FIG. 2. Canker in stem produced by inoculating a pod.

Description of Plate XVI.

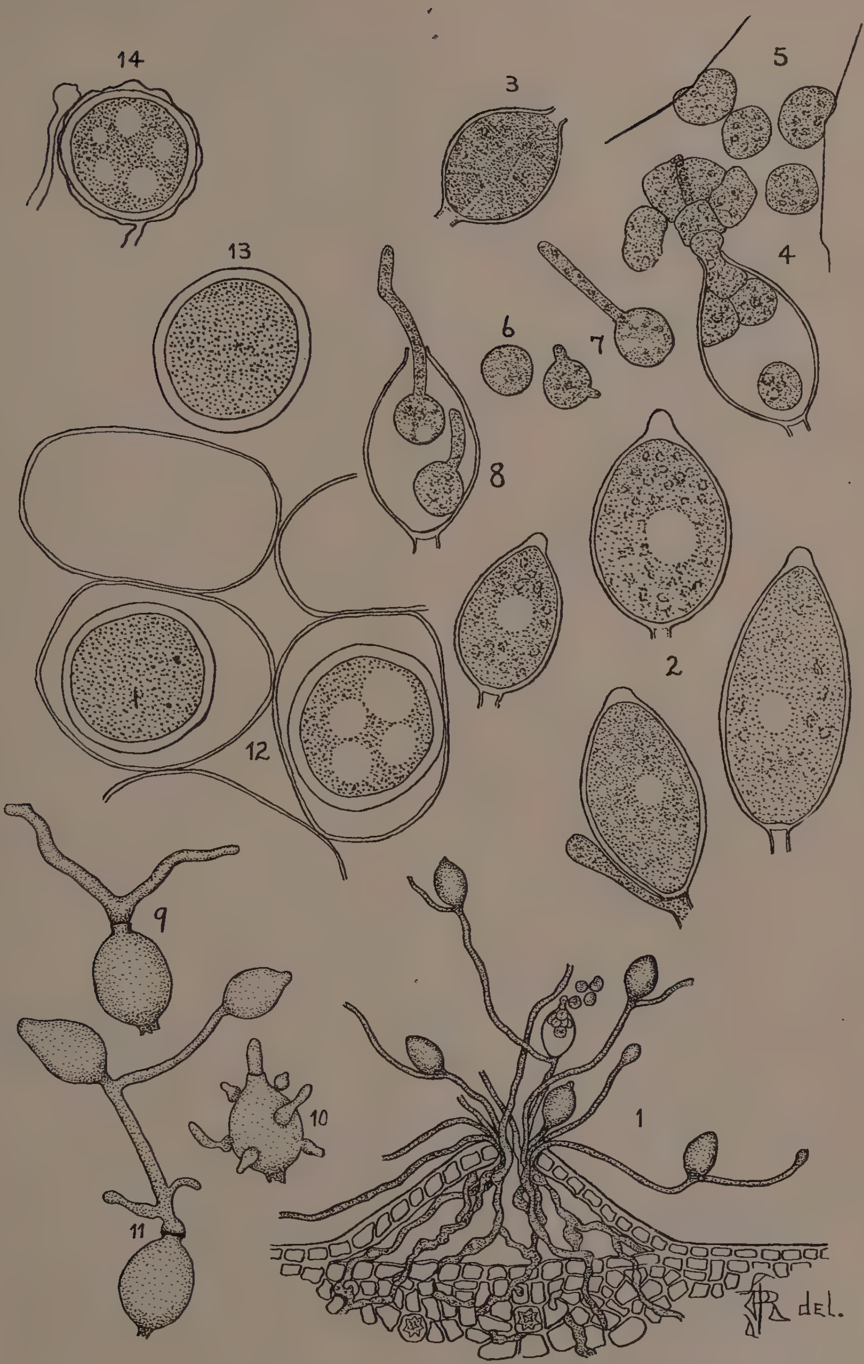
FIG. 1.—One picking from 500 sprayed cacao trees. The large pile contains 1,204 sound pods, and the small pile 73 "black" pods. Fig. 2.—One picking made at the same time from 500 adjacent unsprayed trees The pile to the left contains 778 sound pods, and that to the right 262 "black" pods.

FIG. 1. One picking from 500 sprayed cacao trees. Black rotted pods in pile to the right.

FIG. 2. Picking from 500 unsprayed trees. Black rotted fruit in pile to the right.

Description of Plate XVII.

MICROSCOPIC characters of the pod-rot and canker fungus.—1. A vertical section through a portion of diseased pod showing sporophores of Phytophthora. 2.—Mature spores of Phytophthora showing different shapes and sizes. 3.—A spore suspended in water showing contents beginning to divide into zoospores. 4.—Contents of a spore suspended in water escaping through opening at apex. 5.—Kidney-shaped zoospores. 6.—A zoospore which has lost its cilia and become spherical. 7.—Germinating zoospores. 8.—Two zoospores germinating within the mother spore wall. 9.—Spores germinating with a germ tube from the apex. 10.—Spore germinating with numerous germ tubes. 11.—Germinating spore producing spores. 12.—Resting spores within the rotted pod tissues. 13.—Single resting spore. 14.—Oospore showing oogonium wall and antheridial branch.



Microscopic characters of the black rot and canker fungus.

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FUNGUS DISEASES OF CACAO AND SANITATION OF CACAO ORCHARDS.

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Fungus diseases of cacao have from time to time occasioned considerable losses, and during the last ten years have been under careful investigation. Most of the principal diseases have been dealt with at previous Conferences, but as they have been particularly prevalent in certain of the West Indian colonies during the past two years, it is proposed to present to this Conference a complete review of these diseases, together with the additional information that has been obtained respecting the treatment of them and of the new diseases that have come under observation. Particular attention will also be drawn to the sanitation of cacao orchards, in the hope that assistance may be rendered to cultivators towards reducing and preventing those losses that are frequently overlooked and sometimes, it is feared, totally disregarded.

In old records of the West Indies, reference was made to 'blights' that affected the cacao in different localities, but it was not until 1898 that attention was specially drawn to specific fungus diseases. In that year, some diseased pods were brought under observation in Trinidad and were investigated by the Botanic Department of that colony and by Kew. A year or so later, careful investigations were commenced by Mr. Howard, (then Mycologist attached to the staff of the Imperial Department of Agriculture) of fungus diseases of cacao of Grenada. Since then observations have been continued in Dominica, St. Lucia, and St. Vincent, and the parasitic fungi on the cacao tree have been under thorough investigation. Considerable information in respect to life-histories of the fungi and to remedial treatments of the diseases has been acquired, and it has been satisfactorily demonstrated during the past few years that practically all the different diseases are amenable to treatment. Reliable data in respect to the success of various remedial measures have been forthcoming. It has been shown by the experiment plots, established by the Imperial Department of Agriculture in various districts in the different West India Islands, where diseases had been allowed to develop almost to a maximum, that such diseases may rapidly be reduced to a minimum by careful treatment. The increase in crops thereby obtained, moreover, allowed of a sufficiently good margin of profit over the increased expenditure incurred in cultural operations to commend such treatment for the consideration of all cacao cultivators.

The most important of the cacao districts of the West Indies have been surveyed for the purpose of obtaining information in respect to the occurrence and damage incurred by the different fungus diseases. Observations have recently

been made in Dominica, St. Lucia, and St. Vincent, while cacao at the Botanic Station, Grenada, and in some districts of Trinidad has also been inspected. During last year, Mr. O. W. Barrett was engaged in studies in Trinidad and issued several reports.

It is proposed to group the diseases of cacao under sub-heads: (1) Root disease, (2) Stem diseases, and (3) Pod diseases, while at the end of the article, notes will be given on general sanitary observations for cacao plantations.

ROOT DISEASE.

Attention to a root disease of cacao in the West Indies was first called by Barber in his report on the failure of the Dominica cacao crop of 1892-3. It was recorded to affect also mangos, oranges, coffee, and bread-fruit. In 1901, Howard investigated a root disease in certain districts of Grenada, and recorded that a similar disease affected nutmegs and many other cultivated trees. The opinion was also expressed that Dominica and Grenada diseases might be identical. A similar disease was also known to occur in cacao and coffee cultivation in Jamaica.

Later in the same year, specimens of cacao trees affected with root disease from Dominica were examined by Howard in the mycological laboratory of this Department, and it was found that the roots had been affected by a fungus that closely resembled that observed in the Grenada cacao root disease.

A somewhat similar root disease of cacao is reported to occur in the Cameroons and coffee is affected in Gaudeloupe, while other root diseases have been reported from cacao and other plants in Ceylon, Samoa, and Java.

Recently, investigations have been made into the occurrence of root disease of cacao in the various cacao-producing districts of these islands, and it has been found that this disease occurs fairly commonly in many parts of Grenada, Dominica, and St. Lucia. Remedial measures have been given careful trial, and it has been found that this disease is quite amenable to treatment if taken during its early stages. Examination has been commenced of the fungus that causes this disease, but in spite of the frequent occurrence of the disease, no fructifications have yet been found in the field nor have they been produced in the laboratory.

Clamp connexions characteristic of the Basidiomycetes have sometimes been observed in the fungal hyphae but opinion as to identification of the fungus must be deferred until further investigations have been completed and until fructifications have been obtained.

A root disease of coffee and pois-doux in Guadeloupe has been described by Delacroix, who believes that the fungus observed may be a species of *Dematophora* or of *Rosellinia*. The fungus in Samoa and in Ceylon has been attributed to *Hymenochaete*, and that in Java to *Sporotrichum*.

It is obvious, therefore, that root diseases affect cacao in many widely separated countries, and it is possible that a careful description of the disease known in Grenada,

Dominica, and St. Lucia may be of interest, while the remedial measures that have been found to be successful cannot fail to attract attention. This disease is sometimes alluded to in these islands as 'canker of the root.'

Symptoms.—Trees affected with root disease present a sickly appearance. The leaves become small and assume a yellowish hue, while the branches begin to wither from the tips—the leaves wilting. These branches eventually die off, and subsequently the whole tree may be killed. Trees are rarely killed off singly but usually in patches. These patches of dead trees, unless something is done, increase in size, and it has been observed in Dominica when the disease has been neglected that areas of nearly an acre in extent have been destroyed.

It has frequently been noticed—though this is not always the case—that these patches, when they are quite small, are circumscribed by the spread of roots from trees that have been used for shade. Pois-doux, bread-fruit, bread nut, mango, pomme rose, and avocado pear, which are dead or dying, have been commonly observed in the centre of the diseased area, and it has been suggested that the fungus attacks the dead or dying roots of these trees and then affects the young roots of the cacao. It has undoubtedly been established that the fungus under consideration may spread from affected roots of pois-doux or bread-fruit, and it has been observed to spread for a considerable distance along a pois-doux wind-break from tree to tree.

In Dominica, it has been found that cacao has become affected where none of the above-mentioned trees were present, and it was difficult, owing to the length of time that elapsed since the disease first made its appearance and when investigations were made, to establish clearly at what spot the disease commenced. On this estate, the soil of which appeared to be of uniform quality, a patch of fifteen to twenty trees was killed out, and then at a distance of say about 100 yards another patch was destroyed. The intervening trees were quite healthy and their roots did not in any manner appear to be affected. In this island it has also been found that root disease is fairly prevalent in cacao fields recently planted in cleared forest land, but it is suspected that more than one species of fungi are interested in this trouble, and that the disease may have originated from the fungi found on the decaying logs lying about the fields.

If the roots of a diseased cacao tree are laid bare and carefully examined, it will be found that many of them are black and decayed. Careful observation will reveal the white strands of a fungus mycelium attached to these roots, and passing into the bark and into the tissues of the root. If, however, the bark of diseased roots is peeled off, a white web of fungus mycelium —usually arranged in somewhat star-like masses—will be found between the bark and the wood. This is a typical sign of the disease and is always to be observed in the larger diseased roots.

The mycelium is at first white, then grey, and finally assumes a light-brown colour. From this mycelium, hyphae may be followed into the deeper woody tissues of the roots, and almost

a white rot takes place. During the growth of the mycelium the woody tissues of the root become softer and lighter, while frequently dark-coloured streaks, caused by the accumulation of some gummaceous substance, may be seen distributed throughout the root. Eventually, the water in the soil aids a wet rot, and the diseased roots, except the bark, become quite soft and rotten.

In the younger roots, the typical mycelial threads between the bark and the wood is not apparent, but there is usually a brown discoloration of the inner bark tissues due to gummy substances being formed through the attack of the fungal threads.

When the fungus has invaded all the principal roots or has spread upwards and encircled the lower portion of the stem, the tree dies. The disease, however, is not a rapid one, and when taken in the early stages has been found to be quite amenable to treatment.

Spread.—The spread of the disease is by underground mycelium. It frequently commences, as above stated, from pois-doux, bread-fruit or other trees, and it is seldom that it can be detected in its very initial stages, for when it is noticed several cacao trees—usually in a circle—have been infected.

Remedial Measures.—Whenever pois-doux, bread-fruit, bread nut, mango, pomme rose, or avocado pear trees are noticed in a cacao plantation to be dying, they should immediaately be taken out and burned. Particular care should be taken thoroughly to extract as many as possible of their roots and destroy them. Trenches should also be dug, to cut off the roots of the cacao tree from those of the trees in the infected spots. It is frequently advised that bread-fruit, bread nut, and avocado pear trees should not be planted amongst cacao in new plantations, and when any such trees have to be removed from old plantations care should be taken to extract their roots. The pois-doux is not very often attacked, and, therefore, may be used for wind-belts; but these trees should be carefully watched, for it has been observed that this disease has often commenced among cacao from dead pois-doux.

When an area of cacao is affected, it should be isolated from the remainder of the plantation by digging a trench, about 2 feet deep and 18 inches wide, around the diseased trees. This encircling trench should be connected with the general drainage system to prevent the lodgment of water, and care should be taken to include all the unhealthy trees in the circumscribed area, and to throw the earth from the trench into that portion that has been cut off. The surrounding healthy trees should be kept under observation for some time in order to ascertain whether isolation has been complete. If it has not, a further trench encircling a larger area must be dug.

All the trees in the affected and isolated area must now be carefully examined. The most badly diseased ones should be taken out, their roots extracted, and the whole burned. Others less badly affected should have the soil removed from

their principal roots, and the roots laid bare. The diseased roots should be cut off, and the diseased parts removed and burned. A good application of lime—say 5 lb.—should then be given in the holes that have been made around the trees, while laying bare the roots, and turning back the soil. If a large number of roots have had to be cut off, a good heavy pruning should be given to the tree, in order that it may not suffer from excessive transpiration while possessing a reduced root area.

The whole of the isolated area, after the trees have been separately examined and treated should then be properly forked, and a good application of quick lime—at the rate of about 10 lb. per tree, should be broadcasted. After a time, applications of pen manure and mulchings should be given, and in the following year another general application of lime—at the rate of about 3 to 4 lb. per tree should be made. After the first general thorough forking, it is advisable that further forking should not be given for some years unless the trees are falling back, the land being kept in good tilth by heavy mulchings of grass and leaves. Forking always causes wounds to the roots, and if fungus is present in the soil, it is a means of spreading the disease.

Planters who have followed these remedial measures in Dominica and St. Lucia have saved considerable numbers of trees, and it has clearly been demonstrated that this disease, if it is taken sufficiently early may be successfully treated.

STEM DISEASES.

CANKER.

This disease of the bark of stem and branches of the cacao tree first came into prominence in Ceylon, where it was investigated by Willis, and later more fully by Carruthers about 1897. The latter investigator showed that the disease was caused by a parasitic fungus, which he referred to *Nectria ditissima*, Tul. Attention was called to a disease in cacao in Trinidad by Hart, who in 1898 sent specimens of a fungus on pods of cacao to Kew for identification. This fungus was referred to *Nectria Bainii*, Massee, and it was advised that care should be taken to avert any attempt on the part of the fungus to attack the trunk of the cacao tree on account of the distinctive canker disease in Ceylon being attributed to a species of *Nectria*. Subsequently another species of *Nectria* was found by Hart destroying the bark of cacao trees in Trinidad and was forwarded to Kew. In 1901, Howard investigated a ‘canker’ disease of cacao in Grenada, and the fungus found was referred by Massee to *Nectria theobromae*, n. sp., and stated to be identical with a fungus sent some time previously by Hart from Trinidad. The technical description of this fungus has not yet been published, but it seems to differ from *Nectria Bainii* in its perithecia. Howard also obtained another fungus in Grenada from cankered trees, and this was named by Massee, *Calonectria flavida*, n.sp. This fungus was subsequently noticed in Dominica and also was noted in Trinidad by Hart. A species of *Fusarium* is also associated, but is supposed to be saprophytic.

Inoculation experiments conducted by Howard in Grenada by introducing ripe spores into wounds in cacao trees showed that both *Nectria theobromae* and *Calonectria flavida* were parasitic in habit, for in each case distinct infection was produced. Experiments have yet to be conducted with *Nectria Bainii*, and, as this fungus has only been recorded from pods it has yet to be shown that it may in any way be associated with canker in the stem or branches in Trinidad.

It has been found that *Nectria theobromae* and *Calonectria flavida* may occur together in the diseased area, while at other times they may occur alone. In Dominica, it was supposed at first that the last mentioned was alone responsible for the canker in cacao, but recently *Nectria theobromae* has been found there, as well as in St Lucia.

Although our knowledge of canker has greatly increased in the past few years, and successful methods of treatment have been evolved, it would appear that additional information, especially in respect to the scientific details of the disease, is desirable. A large number of species of *Nectria* have been reported from different parts of the world as parasitic on cacao, and Petch in drawing attention to the position in Ceylon mentions that 'the *Nectria* on the stem is not the same as the *Nectria* on the pods. The former agrees with *Nectria striatospora*, Zimm.' Continuing further he states, that from Java, Zimmerman has recorded *Nectria coffeicola* and *Nectria striatospora* on cacao stems, and *Calonectria cremea* on cacao pods. In South America *Calonectria bahiensis*, Hempel, is found on the stem, while from the Cameroons, *Eunectria camerunenses*, Appel & Strunk, has been recorded.

In October 1906, a species of *Lasiodiplodia* was forwarded to this Department by Hart from Trinidad for examination, and a similar fungus has been recorded from Brazil and San Domingo. Last year (1907) this fungus was found associated with *Nectria theobromae* in cankered areas on cacao trees in Grenada, and recently Barrett has reported that it is common throughout Trinidad and may be responsible for a considerable quantity of the canker present in cacao plantations. *Diplodia cacaoicola* has been reported from Ceylon as causing a canker that differed considerably from that understood as the typical canker of Ceylon.

It will therefore be advisable that a brief review of our knowledge of canker in the West Indies as caused by *Nectria* or *Calonectria* should be given, and the remedial measures that have been found to be successful, indicated. Diseases caused by *Lasiodiplodia* sp., and *Diplodia cacaoicola* will be treated of separately.

Occurrence.—This disease is met with in Trinidad, Grenada, Dominica, and St. Lucia, and I have seen a few cases in St. Vincent.

Symptoms.—By the keen observer canker may be detected in its early stages. The bark of the affected areas presents a peculiar dry, greyish-brown appearance. The best time to look for these areas would appear to be in the dry season

immediately after a shower of rain. These greyish-brown areas do not dry as quickly as the unaffected portions of the bark, and the limits of the affected portions may thus generally be ascertained. If the bark is cut by a knife at these points, it will be found to be slightly discoloured, particularly in the outer layers. Later as the disease increases, the bark of these patches on being cut, presents a deep claret colouration. It is moist and soft to the touch, and if it is removed it will be found that the outermost layers of the woody tissues are affected.

Subsequently, these affected areas split or crack, and allow a brownish-red gummy fluid to ooze out. When this gum dries, it gives a dark rusty appearance to the bark. This is known as the 'bleeding stage,' and the disease is now well established.

In Dominica, cacao plants are often noticed that produce an abnormal number of flowers which never set fruit. This flowering may continue throughout the whole year, and is known as the 'flowering disease.' This, in Dominica, is generally one of the first symptoms of canker, for it has recently been demonstrated that such trees always eventually develop the disease. Whether this condition may satisfactorily be overcome by careful and high cultivation has yet to be demonstrated. A similar extraordinary flowering has been observed in St. Lucia, but it has not yet been satisfactorily ascertained whether it is common.

Canker may affect a branch or a stem, and frequently several spots may be noticed on the same tree. When these diseased areas are numerous, the leaves become small and assume a yellowish hue. The spread of the disease in the bark varies considerably. It may spread quickly round the tree, or may extend in all directions. Branches frequently die off through having become 'ringed,' and not uncommonly whole trees, particularly when the diseased area is near the surface of the ground, are killed. Undoubtedly, canker appears to be the more serious when it attacks the stem at about the level of the ground.

Frequently, under badly diseased cankered areas the woody tissues assume a dark-brown colour. Howard states that the tissues are penetrated by the mycelium of the fungus, but subsequent investigation would suggest that the fungal hyphae penetrate to but a slight distance in the woody tissues, and it is questionable whether they are directly parasitic on the wood.

In the rainy season the fructifications of the two fungi (*Nectria theobromae* and *Calonectria flavida*) may generally be found. White pustules make their appearance through minute cracks in the diseased bark and large numbers of conidia are produced, while subsequently colonies of perithecia make their appearance. They may be yellow (belonging to *Calonectria*) or red (belonging to *Nectria*), and contain the asci containing the ascospores. An exact knowledge of the life-histories of these fungi is not yet complete, and investigations will be continued.

Ripe ascospores have been found to produce infection, when introduced into wounds in the cacao tree, and it is generally held that these fungi are wound parasites.

It has been observed that canker is generally to be noticed more frequently among old trees, and it has rarely been observed on very young ones. A canker on trees six years old has recently been recorded from Dominica, which differs slightly from that above described in certain characteristics.

Spread.—As the fungi that are associated with this disease are held to be wound parasites, particular care should be taken with all wounds, both those made in pruning and gathering the crop, and accidental ones. If attention be given to all wounds, the spread of canker can rapidly be checked. Conditions of dense shade and abundance of moisture favour the spread of the disease, and should receive attention when remedial or preventive measures are under consideration.

Remedial Measures.—Considerable attention has been called to the methods used in combating this disease by officers of the Imperial Department of Agriculture and others, and therefore it is only necessary to summarize those which have proved most successful :—

All dead trees or branches should be cut out and burned. It is preferable that they should be burned on the spot if practicable, but if not, they should be removed to some heap to be burned. Suckers would appear to suffer but little from canker, and therefore it is often practicable to save suckers when a badly diseasd tree is cut down, rather than have to wait for the growth of supplies.

When canker spots are detected on the trees, the diseased bark and wood should be cut out with a sharp pruning knife, care being taken to remove at least a ½ inch of healthy bark around the diseased area. If the affected areas extend for a considerable distance around the stem of the tree, the bark must be removed in stages, or otherwise practically ring-barking may take place. It has been found that the bark from about a third of the circumference of a tree can be removed without seriously affecting nutrition, and after about three or four months more bark may be removed. Thus the gradual removal of diseased bark may be accomplished.

The wounds caused by cutting out the diseased tissues should be cleaned and thoroughly treated with tar. It has been recommended that a mixture of resin oil and manjak may be found to be a good substitute for tar. With this mixture, this Department has as yet had no experience, and therefore continues to recommend tar for application to wounds—a substance, when applied carefully and not allowed to run all down the bark of the stem or branches, that has given satisfactory results. After a tree has been treated, it should be marked by a ring of white-wash or white paint around one of the branches in order that it may be under careful supervision. The diseased portions that have been cut out should all carefully be collected and burned. They should, on no account, be allowed to remain on the ground at the foot of the tree, for disease may spread from them into the basal portion of the stem.

All knives or cutlasses used for cutting out diseased tissues should not be used for pruning purposes, and it is advisable that they should be disinfected before they are put aside. The treated trees should be inspected periodically and further, careful search for canker spots made. This part of the work will be greatly facilitated by the ring of white-wash or white paint that has been advised to be put around one of the branches of trees that have had canker areas removed from them.

The best time for canker work would appear to be during the dry season, for immediately after a shower the affected areas may easily be detected. Further, the wounds appear to heal more rapidly. It should, however, be mentioned that this work is not to be necessarily limited to the dry season, but should be carried on throughout the year, particularly on those properties where canker is at all prevalent.

Experience has shown that the above remedial measures will satisfactorily reduce the quantity of canker, if not entirely eradicate it. Estates, on which carefully conducted measures against canker have been carried out, have given increased crops, and the number of cases of canker has been very largely reduced. The beneficial results obtained by the adoption of remedial measures have repeatedly been noticed on various estates in the West Indies, and although accurate figures are not yet available, yet those available from the Experiment Stations in Ceylon, where somewhat similar measures have been practised, show conclusively that attacks of this disease may be rapidly reduced to a minimum.

In considering preventive measures, it must be borne in mind that the fungi associated with canker are regarded as wound parasites, and therefore one of the duties on the estate must involve careful attention to all wounds. Cuts made in pruning should be smooth and close to the stem or branch, and should be tarred over, and it may also be found possible that those made while picking can be similarly treated. A joint of bamboo, filled with tar, corked at the top end, and with a small spiket hole just above the lower node to allow tar to drain on the frayed lower end, has been found to be a convenient form by which tar may be carried when pruning operations are being carried on. It may be carried in the left hand, and after a branch or a sucker has been removed tar can immediately be rubbed on. This dispenses with the carrying of tins, does not allow of tar being put on to such an extent as to drain down the bark from the wound, and saves considerable time.

Canker is generally worse in plantations that are densely shaded, for the condition of moisture and of semi-darkness assists in the development of the fungi and in the dispersal of their spores. The reduction of dense shade in order to let in more sunlight is strongly to be recommended where disease is prevalent, for it has been found in Ceylon and in other places that this is a matter that should receive first attention. It is possible that the judicious thinning out of shade should receive attention on many West Indian plantations, but it must be adopted cautiously, for it has been observed that the direct rays

of the sun, in some dry localities, have the power of splitting the cacao bark and of causing wounds to which fungus spores may at a later date gain entrance.

It has been recommended that spraying should be adopted throughout cacao orchards to destroy fungus spores with a view to preventing infection, but experimental evidence as to the economy of such a practice for the spores of the fungi causing canker is yet to be forthcoming. Favourable results have been obtained in some orchards in temperate climates from spraying for canker of fruit trees, but no conclusive evidence has yet been obtained in tropical countries.

DIE-BACK.

This disease of cacao was investigated by Howard in Grenada and has subsequently received attention in St. Lucia and Dominica. In St. Lucia it was at one time particularly common, where it probably is the most serious of fungus diseases. It was very prevalent at low elevations on the light soils in the vicinity of sugar-cane cultivation, but can be entirely eradicated from a plantation by high cultivation and the general adoption of sanitary methods. A few cases have been noticed in St. Vincent. A similar disease, caused by the same fungus, has recently been reported by Petch from Ceylon, but does not appear to be very common.

Specimens of the fungus responsible for this disease were forwarded by Howard to Kew, where it was determined by Massee as *Diplodia cacaoicola*, P. Henn., a form reported on dead cacao branches in the Cameroons. This fungus is extremely common on diseased branches and twigs and is also found on cacao pods. Van Hall in Surinam reports a species of *Chaetodiplodia* on diseased cacao twigs, and it is possible that a similar fungus may be found to be associated with *Diplodia* in some of the West India Islands. *Diplodia cacaoicola* has been reported recently from Ceylon as responsible for 'die back,' and for a case of 'canker.'

Symptoms.—The disease commences in the younger twigs and spreads from them to the larger branches. The trees on which the young twigs have been killed, present an appearance that is known as 'stag-headed.' Sometimes cacao trees die back to a slight extent at the extremeties of the branches through poverty of soil, wind, drought, etc., but in such cases there is always a sharp line of demarcation between the dead and dying tissues. If, however, twigs that have been killed by the 'die-back' fungus are cut longitudinally, there is no boundary line between the living and dead tissues. The ends of the twigs are black and quite dead, and then an intermediate brownish-coloured zone is noticed between the dead and living tissues. Microscopic examination reveals fungal hyphae in this transition zone, which are at first colourless and then brownish.

In the rainy season, or even after a good shower, small blackish pustules will be observed to break through the bark. From these, the spores of the fungus may be obtained.

The life-history of *Diplodia cacaoicola* was worked out by Howard, who found that this fungus was parasitic on sugar-cane and on cacao in these colonies. The fungus is a facultative parasite and can live upon dead cacao wood, shells of cacao pods, and upon sugar-cane. The spores are produced in pycnidia just beneath the epidermis. They are produced on short conidiophores, and are unicellular, elliptical in shape, and colourless or faintly greyish. They are liberated from the mature pycnidia by means of the small ostiole at the apex. Soon after they are liberated, the exospore darkens and becomes dark-brown, and at the same time a transverse septum is formed across the shortest diameter of the spore. The colourless spores germinate more readily than the bi-cellular mature spores.

Spread.—Infection experiments conducted by Howard in Grenada point to this fungus being a wound parasite and capable of seriously affecting sickly trees.

The spores are spread by means of wind and rain, and it is only necessary for a wound to be present for infection readily to take place.

It has frequently been noticed that bad attacks of thrips and outbreaks of die-back disease frequently go hand in hand. Whether the thrips may make wounds through which the fungus can gain an entrance has yet to be demonstrated. This is a matter that should receive investigation.

Remedial Measures.—This disease does not readily attack trees in a vigorous condition of growth. Every effort should, therefore, be given to thorough cultivation, all diseased branches and twigs should be cut out and burned, and all wounds thus made should be followed by an application of coal tar or some similar substance.

It has been demonstrated in St. Lucia, by the work on the Experiment Plot at La Perle estate, Soufrière, that the disease may be defeated by high cultivation, manuring, and attention to careful pruning. The disease has practically been eradicated from this estate, and it is reported by Hudson that the yield of cacao has been increased from practically nothing to over 1,000 ℔. of cured cacao per acre, within six years. This fungus is not very destructive to carefully cultivated vigorous trees, so every effort should be made to improve the condition of all unhealthy trees.

Pen manures and mulchings should be applied, and all weeds should be carefully buried. All dead wood and twigs must be cut out of the plantation and burned. The cuts should be tarred.

It is also important that the husks or shells of all cacao pods should be buried with lime, for it has been shown that heaps of old pods lying unburied about a plantation serve as centres of infection for the spread of disease. It has been suggested that cacao shells may be treated with lime on the surface, but it would be preferable that they be buried, for experience has shown that such a procedure isthe most sure and the most economical of all the

various methods that have been experimented with in checking the spread of the fungus that is responsible for this disease and for the 'brown pod rot.'

LASIODIPLODIA.

Towards the end of 1906, diseased specimens of roots and stems of cacao were forwarded to this Department from a Southern district of Trinidad for examination. It was found on examination that large numbers of septate, dark-coloured mycelial threads were present in the vessels of the roots, and in the vessels, medullary rays, and other cells of the stems. Fructifications were obtained in the laboratory, and the fungus was provisionally identified as a species of *Lasiodiplodia*. Specimens were then forwarded to the United States Department of Agriculture for confirmation of identification, with the inquiry as to the similarity between the Trinidad fungus and one under investigation by that Department from San Domingo and Brazil. The fungus on the stem was referred to the species of *Lasiodiplodia* reported as attacking cacao and mangos in Brazil and San Domingo but decision as to the identity of the fungus in the roots was reserved until development of cultures could render its recognition possible.

Further investigation in the laboratories of this Department has shown that the fructifications from the fungal hyphae in the roots appear to be identical with those procured from the stem, and it is more than probable that they were continuous throughout the tissues of the diseased trees.

This fungus was subsequently found on old cankered areas on trees in Grenada, and quite recently on diseased trees from several districts in Dominica. Barrett, while investigating the cacao diseases of Trinidad concluded that practically the whole of the disease in cacao orchards is due to a species of *Lasiodiplodia*, for it infects the fruits, the branches, and the stems by means of wounds and by means of the cushions from which the fruit-stems arise.

Our experience with this fungus has not been sufficiently lengthy to allow of investigations into the complete life-history to be carried out, and it has not yet been definitely established how infection may take place. Infection experiments carried on at Dominica showed that the fungus is weakly parasitic in habit, and, therefore, it may be supposed that infection might take place through wounds. Whether infection of the roots may take place, has yet to be established. In Trinidad it was supposed that the fungus spreads rapidly in the tissues, and consequently the disease kills off trees rapidly: but experience in Dominica would indicate that the course of growth of the fungus is slow, for trees may be affected for some time before they are killed out. High cultivation and careful manuring have been beneficial in Dominica, but the fungus is generally to be found in districts where the soil is not particularly suited for the growth of cacao.

In Grenada, the fungus was obviously associated with canker, and appeared to be following old areas affected previously with *Nectria*. In Trinidad, canker is attributed to this fungus, as also is a disease of pods.

A scabby appearance of pods, in which small, blackish corky patches are developed on the surface at intervals has been observed in Grenada, and a similar appearance of pods has been found in certain parts of Dominica. The pods do not grow to quite the full size, but generally do not decay. The beans are often small and undeveloped. When such pods are placed in a damp chamber they invariably develop the fungus *Lasiodiplodia*, but it does not appear to have occasioned much damage.

Remedial Measures.—Until further information has been gained of this fungus, definite remedial measures cannot satisfactorily be indicated. Where trees are affected, as in Dominica, and present a dwarfed invigorous appearance with dying back of branches, and dark-black fructifications pushing through the bark, they may generally be cured by high cultivation, careful drainage, and manuring. Where the fungus affects the bark and produces a 'cankered' appearance, resource should be had to the remedial measures indicated above for the typical canker disease of the stem.

PINK DISEASE.

This disease was first noticed in certain localities of Dominica, but it has subsequently been found on some estates in St. Lucia. It does not at present appear to be of a very serious character and can satisfactorily be kept in check.

Symptoms.—The smaller woody branches of cacao frequently become covered with a pinkish incrustation of adpressed fungal hyphae. This, in younger branches, spreads all over the surface, while in the older branches it is usually to be found only on the surface of damper and more shaded sides.

Fungal threads from this pinkish mass push into the tissues of the bark, and may sometimes in small branches penetrate into the deeper tissues of the wood. The bark eventually cracks and splits, and then peels off. Generally it has been found that new bark has been formed, and it is not often that branches are killed off through fungal hyphae penetrating into the deeper tissues.

The fungus (*Corticium lilaco-fuscum*) that causes this disease is the more noticeable in damp, shaded situations, and during the rainy season, but cracked bark, showing where the branches have been attacked, is easily recognized during the dry portion of the year. The fungus may spread all over the surface of a branch and to other branches.

The chief danger of this fungus would appear to be that it causes cracks in the bark of the affected branches that serve as wounds for the entrance of spores of *Nectria*, *Diplodia*, etc., and, therefore, unless it is kept in hand, it may be the means of assisting the rapid spread of diseases throughout the plantation.

It should also be noted that another species of *Corticium*, viz.—*Corticium Javanicium*, Zimm., is reported upon many kinds of trees from Java, Ceylon, and Southern India. It destroys the bark, and kills small branches. Larger branches are not so badly affected, but it initiates canker.

Remedial Measures.—The fungus may be destroyed by washing the affected branches with a lime-sulphur wash. This may be made by mixing $7\frac{1}{2}$ lb. of slaked lime with $2\frac{1}{2}$ lb. of flowers of sulphur in 10 gallons of water, and boiling until the mixture turns orange in colour. When cold this mixture should be well rubbed on the parts of the branches affected.

All the younger branches that have been killed out should be cut off and burned, and even some of the larger ones it might be advisable to remove.

THREAD BLIGHTS.

Thread blights on cacao were first found in St. Lucia in 1904 and were described by Lewton-Brain at the fifth Agricultural Conference held at Trinidad in 1905. They have also been found in Trinidad, Dominica, Tobago, and British Guiana. During last year, several different thread blights on a variety of plants were forwarded for examination to this Department from Trinidad.

Symptoms.—Thread fungi generally consist of sterile mycelial threads or strands of various colours running irregularly up and down on branches and stems, and closely adpressed to the bark. The delicate strands of mycelium sometimes form swellings before branching takes place. They generally spread upwards over all the younger twigs and buds, and then not unfrequently pass to the leaves, and appear on their under surfaces in the form of a network of fine filaments. Where two leaves touch, these filaments spread from one to the other, sometimes forming a thickened cushion at the point of contact.

Microscopic examination of these mycelial strands shows that they are composed of parallel-running fungal hyphae closely woven together. From the under side of these strands, numerous hyphae are given off into the bark of the twigs, and in the case of young twigs they penetrate through the cortex into the deeper tissues—thus causing the death of the attacked portions. Similar hyphae also penetrate from the strands on the under surface of the leaves into the deeper tissues and also into the tissues of buds. Leaves and buds may, therefore, also be killed by the fungus.

Specimens of different thread fungi have been carefully examined, and it has been found that the mycelial threads are not composed of similar hyphae. It is extremely probable, therefore, that these thread blights do not represent the same fungus in all cases. Fructifications have not yet been obtained, but it is possible that some of them belong to the Basidiomycetes, for clamp-connexions have been frequently noticed.

'Horse hair blight' resembles closely a tuft of horse hair caught in the twigs. Some of the threads are closely attached to the bark, and send in hyphae into the deeper tissues of the branches. Specimens of horse hair blight have been sent by Hart from Trinidad to Kew for identification. The fungus was determined as *Marasmius equicrinus*, Mull.

Spread.—The chief method of spread is by means of the threads on dead twigs, leaves, etc., being blown or caught in the branches of healthy trees. In India, thread blights have been spread from jungal trees on to tea, while in Ceylon similar diseases are known on nutmegs and tea. In Java these have been found upon coffee.

Remedial Measures.—Thorough and constant pruning and burning of all diseased material appear to have kept the disease in check in St. Lucia. It is still occasionally found in damp, shaded portions of plantations, but does not threaten to be a serious disease. All wild trees near cacao plantations that are affected with thread blights should be pruned back, so as to avoid the danger of spread of the disease from them to the cacao, and shade should sometimes be reduced. Applications of lime and sulphur wash, as recommended for 'pink disease,' to the fungal threads are also recommended, where heavy prunings cannot satisfactorily be given.

WITCH BROOM DISEASE.

This disease has proved most serious in the cacao plantations of Surinam and has been under most careful investigation by the agricultural authorities there. It has recently been reported from one or two localities in British Guiana, and has been found in a single instance in Trinidad.

Symptoms.—The symptoms are well known. The twigs are affected in the bud state. Hypertrophied growth takes place and there is a tendency towards making many side branches, and producing clusters of twigs resembling brooms. The fruits are also affected by the fungus. When young they often show a small swelling on one side, which frequently may be rather difficult to detect except by the trained eye. At other times simply a discoloured spot is noticed, which later, as the tissues die, becomes black. The pods do not grow to a normal size, but become excessively hard. This symptom the planters call 'petrification,' and affected pods may easily be distinguished from pods attacked by other diseases.

The fungus responsible for this disease was described as *Exoascus theobromae*, Ritz Bos, but the characteristic fructifications of this fungus are extremely difficult to find. It has however been shown that the witch broom of the twigs is caused by the same fungus as the 'petrifaction' of the fruits.

Remedial Measures.—The disease has done a considerable amount of damage in Surinam, and efforts have been made to find measures of control. A heavy pruning of all infected trees and spraying with Bordeaux mixture have been given a careful trial, and some encouraging results have been obtained. If the experiments continue to be successful, they may lead to important conclusions towards solving a problem of great moment to that country.

This disease has not yet made its appearance in any of the West India Islands, and every effort should be made strictly to enforce the Plant Protection Acts that have, within the last few years, been passed to prevent the spread of diseases throughout these colonies.

POD DISEASES.

BROWN ROT.

This disease occurs in all cacao-growing districts of the West Indies. It was first investigated by Howard in 1901 in Grenada, and has been noted in St. Lucia, Dominica, St. Vincent and British Guiana. In some instances, particularly when weather conditions were favourable for the spread of the fungus, it has occasioned considerable damage, but it has been demonstrated that properly conducted preventive and remedial measures will easily keep this disease in check.

Symptoms.—The brown rot of cacao pods is caused by *Diplodia cacaoicola*—the same fungus as the die-back disease of the stem. The disease commences as a small, brown, almost circular spot at either end of the pod or along one of the grooves. It is most commonly seen to commence from the basal end of the pod attached to the tree. This brown decay spreads rapidly all over the pod, destroying the rind. Subsequently it spreads into the centre of the pod and destroys the cacao beans, which are enveloped by a greyish-brown mass of fungal mycelium. The pods usually become soft and rotten, and eventually fall from the trees. Diseased pods are generally the more common near the 'breaking places' particularly on those estates on which burial of husks or shells is not greatly practised.

From the brownish-coloured diseased areas small pustules may be seen bursting through the rind of the pods, and emitting a greyish-white powder. These are the unicellular, colourless spores of *Diplodia cacaoicola* and subsequently they become bi-cellular and dark brownish-black in colour. The whole pod eventually becomes black from the mature spores given off from the numerous pustules.

Investigation has shown that this fungus on the pods is identical with the one that causes die-back of the stem, and infection experiments carried out by Howard, and subsequently repeated, show that it is parasitic in habit. The fungus is frequently found upon old cacao husks, and therefore is grouped with the facultative parasites.

Remedial Measures. This disease may readily be kept in check by collecting all diseased pods and burying them, together with all husks and shells, with lime in trenches or pits. Ripe pods that show the brownish diseased areas should at once be picked in order to save as many of the beans as possible.

Experience in most of the West India Islands has shown that the burial of husks and diseased pods is a means of checking the disease, and owners of estates that have followed this practice will testify to the considerable reduction in diseased pods. Some estates in Grenada and St. Lucia have greatly reduced their losses by adopting the above measures.

It has been suggested that treatment of shell heaps with lime on the surface might be equally as effective, but evidence on this point has yet to be obtained. It is doubtful, however,

whether such a system could be as strongly recommended as burial.

This disease is still very common in several parts of the West Indies, and is generally to be found in damp, shaded situations. It is possible that some reduction of overhead shade may, in some instances, be productive of beneficial results.

An epidemic of the disease could be checked by spraying the pods on the trees of a plantation with Bordeaux mixture, after the most badly diseased ones have been removed. Spraying for pod diseases has been experimented with by Wright at the Experiment Stations in Ceylon, and it was found that the number of fungus-attacked pods could considerably be reduced by systematic spraying, and that the increase in the crops showed considerable profit above the expenditure incurred by the operations. It was stated, however, that the results of different experiments showed that spraying could only be advised for the fruits, and should be carried out at the setting of the young fruits or during crop time.

BLACK ROT.

This disease is common in Trinidad but has also been found at St. Lucia, St. Vincent, and British Guiana. Attention was first called to it by Hart in 1898, when it was found that a larger percentage of the crops in many districts in Trinidad were being destroyed. Investigations by the Botanic Department of Trinidad, and by Kew showed that the disease was due to the fungus *Phythophthora omnivora*, De Bary.

Symptoms.—The attacked pods turn black and are then covered with the white mycelium of the fungus which produces larger numbers of ovate conidia. These may be carried by rain or wind to other pods, and if conditions are suitable they may germinate at once, penetrate the tissues and further produce the disease. The mycelium of the fungus spreads rapidly in the substance of the pod, and resting spores (oospores) are formed by a sexual process—thereby enabling the fungus to satisfactorily tide over periods that may be unfavourable for its growth. These oospores are liberated on the decay of the fruit, when they germinate and start the disease again.

The pods affected by this disease usually assume a dense black colour, become hard, and often hang, covered in places with white fungal mycelium and conidia, on the branches for a considerable period before they fall.

Remedial Measures.—Diseased pods should all be collected and buried with lime in order to destroy the superficial conidia and the deep-seated oospores of the fungus.

It is advisable also that all husks and shells, as advised in the remedial measures given for the 'brown pod rot,' should be buried with lime. A reduction of shade might be practised in some localities, for too moist and shaded a situation favours the growth of the fungus and the spread of the disease.

In epidemics, spraying with Bordeaux mixture should be resorted to, and on those estates where this disease is generally prevalent carefully conducted experiments to ascertain how much disease may be prevented by periodic and systematic sprayings should be carried out.

The adoption of the removal of all diseased pods and burial together with husks with lime has been general on many Trinidad estates, and the extent of the disease has been considerably reduced.

SCABBY POD.

Cacao pods showing small, irregular brownish-black corky areas produced at intervals all over their surfaces have on several occasions been forwarded to this Department from Grenada. Others have also been found in Dominica. These pods do not grow to full size and the quality of the beans is poor.

Microscopic examination of these corky areas showed the mycelium of a fungus beneath them, but it could not be ascertained whether this mycelium extended to any considerable depth in the tissues. On placing the pods, however, in a damp chamber, fructifications of a species of *Lasiodiplodia* always made their appearance and, therefore, this peculiar appearance of the pods will receive further attention.

Further investigation will be conducted into the nature of this disease, and its economic importance endeavoured to be ascertained. At present, however, it does not appear to be very common, nor does it seem to occasion much damage.

NECTRIA.

In 1898, Hart sent from Trinidad pods affected by *Nectria Bainii* to Kew for examination. This supposedly parasitic fungus does not appear to be very common. It causes 'semi-circular dark blotches to appear on the pods, the diseased portion becoming soft and watery.' Later these become covered with a yellowish and orange-coloured mycelium, from which are given off small red perithecia.

During investigations in Dominica, St. Lucia, and St. Vincent, species of *Nectria* were very rarely found upon living cacao pods and these did not always belong to the same species. A further investigation into the life-history of this fungus and into its distribution, as well as of other species of *Nectria* found on cacao, will have to be carried out before it can definitely be stated whether *Nectria Bainii* is of great economic importance.

Remedial Measures.—The measures recommended for the control of the brown or the black rots of pods would probably be effective in keeping any outbreak of this fungus in check.

SANITATION OF CACAO ORCHARDS.

Having given descriptions of the several fungus diseases of cacao in the West Indies, it is here intended to indicate as briefly as possible the principal points for consideration towards maintaining the health of the trees and preventing disease.

A considerable amount of knowledge of the life-histories of many of the fungi parasitic on cacao has been gained during the past few years, and efforts have been made to fight the different diseases. In many cases, however, further inquiry into the life-histories of the fungi under consideration is still necessary, in order to ascertain when the direct remedial measures may be employed with the best prospect of success. Additional investigations will have to be made in order to elucidate clearly the relations that exist between the various parasites and the cacao tree. Further study must also be made of the remedial measures against these diseases in order to assure that the most direct and economical methods are being adopted. Subsequently, a thorough scientific investigation of the different species of the fungi on cacao —saprophytic as well as parasitic—will have to receive attention.

If the remedial measures given above for the various diseases are carefully studied, it will be observed that it is recommended that considerable attention should be given to careful and thorough cultivation. Results obtained on the experiment plots of the Imperial Department of Agriculture established in the various West India Islands, have shown that high cultivation and judicious manuring are followed by the best returns. Expenditure on tillage, drainage, and manures is followed by increased profits, and the vigour and health of the trees are improved.

For the supply of humus for cacao estates it may be found necessary in some localities in these colonies to set aside areas on the estates for the growing of grasses, or leguminous crops, that may be used in the plantations either as mulch or in the form of pen manure.

It has frequently been observed by scientific workers in other countries that when conditions of soil or climate are such as to interfere with vigorous and healthy growth, changes may take place in the tissues of the host plant which may favour the development of the fungus and enable it to do considerable damage with great rapidity. Healthy development may, on the other hand, assist the plant in resisting attacks of fungus or making its inroads unimportant.

Pen manures have been found to be especially valuable, and the healthy vigorous condition of trees after the adoption of mulching and the judicious use of weeds both in Dominica and in St. Lucia can but recommend this practice for consideration at the hands of cacao planters.

Careful attention should be given to pruning and to canker excision. Several of the fungi of the cacao tree are wound parasites, and therefore it is necessary that all wounds whether

made by pruning, or caused accidentally, should be looked after. In pruning, it is necessary that the cuts should be as near the main trunk or branch as possible. They should be smoothed off with the pruning knife and should all be coated, as soon after the cuts are made as possible, with an application of tar, paint, resin oil and manjak, or some similar mixture. Tar has been largely used in the West India Islands and has proved generally satisfactory. Care must be taken, however, that it is not allowed to be smeared down the bark of the trees, for it appears to have some injurious effect upon it and upon the flower shoots that are given out. When confined to the cut surface of the wound, it answers well, especially if applied during the dry season. Canker excision for this reason, as well as for several others—such as ease of detection of cankered areas, less active flow of sap, and greater rapidity of wound healing should be carried out during the dry months. The important work, however, should not necessarily be confined to this period, particularly on estates where the disease is prevalent.

Care should also be exercised during picking, for many of the wounds made during this operation, particularly by the cacao hook, have been sufficient for canker to commence in.

All suckers, except where they are needed for use in shaping the tree or for replacing it, should be removed periodically and the cuts tarred. It has been experienced in Ceylon and also in the West Indies that suckers are sometimes less liable to canker than old trees, and therefore it is often possible to save a sucker or two from the basal portion of the tree to take the place of the diseased tree when it is removed. The adoption of this plan makes it possible frequently to replace a diseased tree in a shorter time than would be required by the growth of young supply plants.

Wounds caused by the falling of portions of shade trees or of bananas and plantains should always receive immediate attention, and all the injured branches should be removed. The wild plantains, such as the cokoi of Dominica, appear to suffer less from wind than the cultivated varieties, and are useful in the establishment of young cacao cultivations.

Dead branches caused by the falling of trees or plantains above referred to, and all branches killed out by either *Diplodia*, canker, or root disease should be cut out, removed from the plantation and burned. Many of the fungi of cacao are facultative parasites and can live and increase upon these dead branches and twigs if they are allowed to remain on the estate. Diseased bark excised when treating canker should also be collected and burned. It should never be allowed to remain at the base of the tree from which it has been cut.

All diseased pods, and husks of pods after they have been broken, should be collected and buried in pits or trenches with lime. It has been found that such procedure is productive of the best results, and should be adopted until experimental evidence is forthcoming as to the value of the suggested treatment of such pods and husks upon the surface of the soil.

Cacao should always be protected from wind. Wind-swept orchards suffer more from disease than do well protected ones. The trees are not so vigorous. Nor do they bear so heavily. Wind belts should be established throughout plantations where necessary. Pois-doux and galba are useful for this purpose, but in some cases overhead shade of bois immortel is relied upon for protection from wind. In St. Lucia, several instances of shading with bois immortel has been productive of much good on estates suffering from 'die-back,' but it must also be recorded that in several localities in some of these islands some reduction of shade might judiciously be made, for a moist atmosphere and densely shaded conditions are extremely favourable for the development and spread of fungi. It has frequently been found in some parts of Dominica and St. Lucia that the gradual removal of shade trees, or of some of their branches, has served as a factor in the control of canker. In Ceylon, the letting in of sunlight is strongly recommended, but it is necessary in the West Indies that it should be adopted cautiously, until experimental evidence is forthcoming, for quite a number of factors have to be taken into consideration.

Where cacao trees, pois-doux or other trees in the orchards die from root disease, they should immediately be removed and burned. The roots should be extracted, and burned with the stems and branches. Trenches should be dug around the affected areas, and large applications of quick lime should be given. The fungicidal properties of quick lime have yet to be fully appreciated, and the use of this substance is valuable in the control of the root disease. Drainage should also be attended to, for root disease has been noticed to be generally worse on water-logged, low-lying soils. The susceptibility of bread-fruit, bread nut, and certain other trees to attacks of the fungus responsible for root disease of cacao would suggest that these trees should be excluded from all new plantations of cacao.

In those plantations where they are at present growing, they should be carefully watched, and when showing any signs of disease should be taken out and burned. When it is thought desirable, at any time, to cut down any of these trees, particular care should be taken thoroughly to extract as many roots as possible and to destroy them by burning.

Spraying for pod diseases has been experimented with in Ceylon and the results warrant experiments being conducted on West India estates as a means in the prevention of similar diseases. A good trial should be given, and accurate figures of the increased expenditure incurred in carrying on such operations should be kept for a series of years. Definite information as to the value of spraying for prevention of pod diseases would then be available, and would indicate whether such operations should be generally adopted as routine estate practises.

In conclusion, it should be added that considerable information in respect to diseases is available for the cacao planter, and trials of remedial measures have shown that they

are all practically amenable to treatment. Further investigations are in hand and it is expected that additional knowledge of the different fungi will shortly be forthcoming. It must be pointed out, however, that the mycologist must always occupy more or less the position of the 'specialist,' while the various agricultural instructors and the planters themselves must be the 'general practitioners.' They should adapt the suggestions for remedial measures to suit local conditions and they may render valuable service to an important section of West Indian agriculture by recording observations on diseases and their treatment, for the information and guidance of Agricultural Authorities.

NOTE ADDED :—While this paper was passing through the press, the technical description of *Nectria theobromae*, Massee has been published in the *Kew Bulletin* No. 5, 1908. It is here reprinted, in order that comparisons may be made with the description of *Nectria Bainii*, Massee, given in *West Indian Bulletin*, Vol. 1, p. 425 :—

'*Nectria theobromae*, Massee, –*Perithecia* gregaria vel sparsa, superficialia, ovata, levia, glabra, aurantiaca-rubescentia, ostiolo minuto vix prominulo hiante. 0·5 m.m. alt. *Asci* cylindracei, stipitati, octospori, paraphyses septatae, ascos excendentes, hyalini, apice vix incrassato, interdum flexuoso, 3 Microns crasso. *Sporae* obligue monostichae, hyalinae, ellipsoideae, 1-septate, ad septum subconstrictae, 28-30 × 8-10 Microns G. Massee.

'This appears to be one of the various species of parasitic fungi that form bleeding wounds in the bark of the cacao tree. *Nectria Bainii*, Mass., previously described as forming similar wounds on cacao pods, differs from the present species in having the perithecia shaggy with golden-yellow scale-like hairs.'

DISCUSSION.

HON. E. G. BENNETT (St. Lucia) said he had been very much puzzled in determining certain diseases that had been affecting his cacao estate, which was situated in the Cul de Sac district, but from the descriptions given by Mr. Stockdale, he was satisfied now, that besides thrips and canker, his trees had been suffering from attacks of 'root disease' and 'die-back.' One peculiarity of 'die-back' was, that notwithstanding manurial treatment and application of remedies recommended, there was a periodical appearance of the disease just about the time that the cacao was approaching maturity. With regard to thrips, whether they preceded *Diplodia* or followed it, he was not sure, but his experience was that he noticed *Diplodia* long before he observed the thrips. Since reading the interesting papers by Dr. Watts on the subject of mulching, which had been published in the *West Indian Bulletin*, he had

commenced to mulch his trees, but had not been doing so sufficiently long to arrive at any accurate statement as to results.

Hon. J. G. W. HAZELL (St. Vincent) asked what kind of tar was used for application to wounds made by pruning.

Mr. STOCKDALE replied that coal tar was generally used, and mentioned that care should be taken in its application. It should be confined to the wound itself, and should not be smeared over or allowed to run down the bark of the tree.

Mr. A. R. C. LOCKHART (Dominica) said that his experience was similar to Mr. Bennett's. Trees that had been perfectly healthy for several years suddenly developed disease. The belief of the common people in Dominica was that the disease was the result of the tap root of the trees coming into contact with some unsuitable layer of soil. What that was worth he did not know, but he mentioned it for what it was worth.

Hon. W. FAWCETT (Jamaica) said that root fungus was more prevalent at Jamaica than anything else. It affected various kinds of coffee, cacao, logwood, and also West Indian cedar. It was necessary to isolate the trees and prevent the disease spreading from root to root, by digging the trenches to a depth of about 2 feet. He had observed trees dying here and there, and on examination, found that they were attacked by fungus. Knowing the history of the estates, he had called attention to the fact that the decaying roots of bamboos or the trees which had been cut down were left in the soil. He did not think however, that that alone would enable attacks of fungus to kill healthy cacao trees. The fungus might be there in the ground, but it could not do any harm unless it got a sudden increase of strength to enable it to attack the living trees around it, or the living trees themselves became unhealthy on account of some condition of drought or soil, and then the fungus had power to attack a tree and kill it.

The PRESIDENT thought that Mr. Fawcett was quite right as to the root disease of cacao being of a similar character to the root disease that attacked coffee and other trees. It was evidently a fungus that existed in the soil and spread in the soil, and would possibly attack anything that came in its way and was suffering from want of vigour. The only remedy it seemed, was that when a tree was dead or dying, it should be taken up at once and the soil treated with lime. In some cases, like that of a cacao tree which had not gone too far, the roots should be examined, and those that were attacked should be cut out. Infected trees also should be isolated by digging drains around them so as to prevent the spread of the disease.

He would add that Mr. Carruthers, who at one time was Mycologist to the Government of Ceylon, after a careful study of the circumstances there, found that an essential part of the treatment of cacao canker was the letting in of sunlight amongst the cacao trees. This had subsequently been experimented with at the different Experiment Stations, sometime under the charge of Mr. Wright, and the results obtained

should be carefully considered by all cacao planters. The gradual reduction of shade had very frequently a distinctly beneficial effect in lessening the attacks of disease.

He might mention that the Government of Trinidad had recently engaged Mr. Barrett, of the United States Department of Agriculture, for the purpose of investigating the diseases affecting cacao trees in Trinidad. When Mr. Barrett's final report was sent in, he thought it would be desirable for the Imperial Department of Agriculture to go carefully into the whole question and prepare a summary of the circumstances stated by him, and the recommendations made by him, and put them on record.

He also alluded to the danger of introducing cacao beans from one colony to another from the disease point of view, and strongly urged that no cacao should be introduced for planting purposes from the continent of South America, owing to the presence there of the 'witch broom' disease. Most of the colonies had Plant Protection Laws, but the greatest caution should be exercised against what has proved to be a most terrible disease of cacao orchards.

Department of Agriculture Federated Malay States

Bulletin No. 14.

THE DIE-BACK DISEASE OF PARA RUBBER

AND A NOTE ON THE LEAF DISEASES OF PARA RUBBER.

BY

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Kuala Lumpur, Federated Malay States
August, 1911.

PREFACE.

Bulletin No. 9, the title of which was "The Die-back Fungus of Cacao and of Para Rubber," was issued by the Department of Agriculture in June 1911. The work comprised an account of investigations on the fungus *Thyridaria tarda* which were commenced under the direction of Mr. George Massee, V.M.H., F.L.S., Principal Assistant at the Royal Herbarium, Kew, and Plant Pathologist to the Board of Agriculture, England, on cacao material from the West Indies and West Africa, and were completed on Para rubber in this country. The conclusions as to the parasitic action of the fungus were based on the results of investigations on its life-history. Since much of the work was necessarily of a technical nature, it was decided to issue an account of the disease in a form in which it may be of more interest to the practical cultivator, and to illustrate it with photographs and woodcuts, which it is hoped will enable the cultivator to recognise and to identify the fungus and its effects with some degree of facility; hence, the origin of this Bulletin, No. 14.

L. LEWTON-BRAIN,

Director of Agriculture, F. M. S.

August, 1911.

THE DIE-BACK DISEASE

OF

PARA RUBBER.

By Keith Bancroft, B.A. (Camb.).

THE HISTORY AND DISTRIBUTION OF THE FUNGUS.

The die-back disease of Para rubber, which is attributed to a form known as *Diplodia*, concluded to be a stage of the fungus *Thyridaria tarda*, was first recorded by Ridley* in the Federated Malay States in 1909. It also appears to be likely that Gallagher† had the same fungus in view in his "Preliminary Note on a Stem and Branch Disease of *Hevea Brasiliensis*." Subsequently, Petch** published an account of the disease from Ceylon in 1910.

The fungus itself was first recorded on cacao‡ from Ecuador as early as 1892. Since then it has been known as a parasite on cacao in many countries and has also been recorded on several other plants in different parts of the Tropics. It possesses an almost world-wide distribution through the Tropics, occurring in the West Indies, South America, St. Thome, West Africa, India, Ceylon, the Malay Peninsula, the East Indies, Samoa and the Philippines.

As a parasite on cacao the fungus has never been regarded as being likely to cause serious damage to the industry, except perhaps in the Island of St. Thome and in Grenada (West Indies). A quantity of material was examined from both of these Islands and, from the fact that the *Diplodia* was usually associated with other parasitic

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* Agricultural Bulletin Straits Settlements and Federated Malay States, Vol. VIII, p. 310, 1909.

† Bulletin No. 6, Department of Agriculture, F.M.S.

** Circulars and Agricultural Journal, Royal Botanic Gardens, Ceylon, Vol. IV. No. 23, 1910.

‡ In order to avoid confusion with coca, cocoes, coconut, etc., the plant which yields cocoa of commerce is called by the above name, *cacao*.

fungi and from a general knowledge of the nature of the *Diplodia,* it was assumed that by no means all of the damage could be attributed to it. The fungus comes on readily on parts of plants which are dying or recently dead and possesses a capacity for very rapid growth, so that it frequently tends to mask the real cause of the trouble. In this country it has frequently been found to follow on the "pink fungus," on attacks by root fungi, and on a bad condition of health induced by inefficient drainage and bad cultivation generally. The question of its becoming epidemic has been frequently raised, and it may be accepted, from a knowledge of the capacity of the fungus for causing disease, that the fungus cannot be reasonably expected to cause any serious injury to the industry unless it follows on some other pest, epidemic in magnitude, which provides it with a ready access to the plant.

In addition to occurring on cacao and Para rubber, the fungus has been shown to be parasitic on tea, *Albizzia* and dadap in Ceylon, on sugar cane, cacao, coconut and *Castilloa elastica* in the West Indies, on mango in St. Domingo, on papaw in Samoa and on sugar cane in India. It also develops readily on dead and dying plant material of very many kinds; in fact, it is so commonly met with on dead parts of plants in this country and it effects such a rapid growth that considerable caution must be exercised in diagnosing the die-back disease. A clear idea of the symptoms must be formed along with a proof of the absence of other parasitic organisms before the effect can be attributed to the fungus with any degree of certainty. In other words, the presence of the fungus on dead or dying parts of plants is of itself no proof that the trouble has been initiated by the fungus.

The fungus has been met with in Selangor, Perak, Negri Sembilan, Johore, Pahang and Malacca. It may, therefore, be concluded to be widely distributed through the Malay Peninsula.

THE DISEASE.

The disease may commence on any portion of the stem; most usually it occurs in the region of the branches, but it may also commence on any part of the trunk. The symptoms may take the form of a "dying back" or, less frequently, a "canker" of the affected part. The fungus enters only at a dead surface, such as dead branches or parts of branches and wood which has died from exposure

or from the action of fungi or animals. Repeated attempts to inoculate plants by applying the spores to an unbroken surface have failed. In the photograph 1 the effect of

Photograph 1.

inoculating a seedling at a wound is shown. The control plant which was not inoculated is seen to be healthy.

Usually, a single shoot dies; it may be the "leader" or it may be one of the lateral branches. The fungus obtains an entrance into the shoot through some dead part and accumulates a growth in the wood adjacent to the point at which it enters. The resultant effect is the death of that portion of the shoot and the consequent death of the parts above it. The upper parts, above the point of entrance of the fungus, are cut off from the supply of water from below and consequently wither and die; the leaves at first remain attached, but they finally fall or are blown off by

the wind, thus leaving the upper parts of the shoot bare. The primary effect is, then, the death of a certain terminal portion of the shoot; the length of this portion depends upon the distance of the point of entrance of the fungus from the tip of the shoot, it may involve only the uppermost two feet of the shoot or it may involve the greater part of the length of the shoot. After this terminal portion has died, the disease spreads downwards and reaches the base of the shoot. From thence it may spread to the main shoot and down to the trunk, affecting the other branches as it passes downwards and finally killing

Photograph 2.

the tree to its very base. In the photograph 2 a tree is shown with its leading shoot bare of leaves, while the other shoots are apparently healthy. This represents a case in which the "leader" has become attacked by the disease, while the other shoots are not yet affected. In the

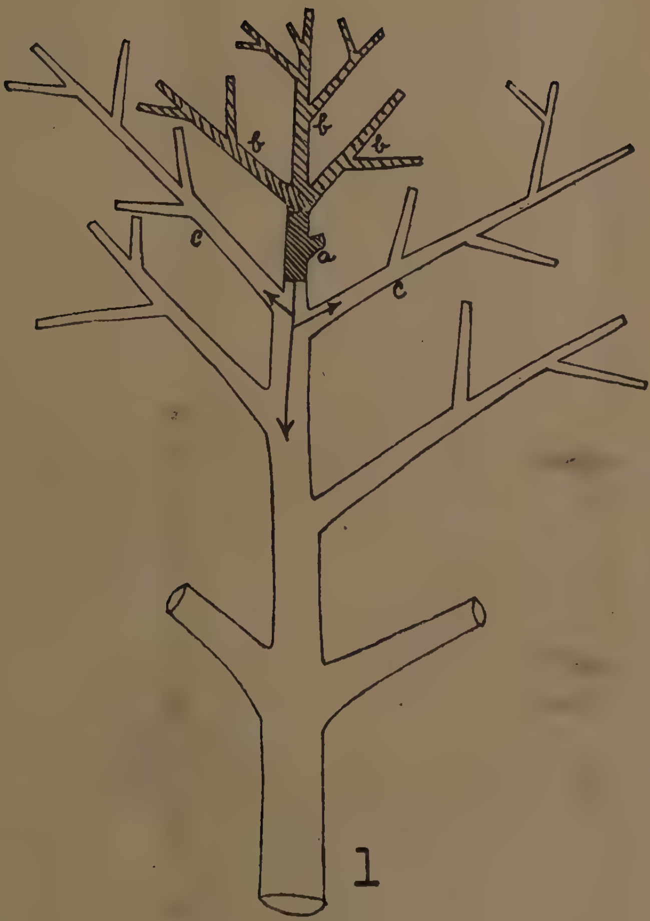

Diagram 1.

diagram 1 the axis of an infected tree is indicated; at *a* the fungus is supposed to have entered through a dead or broken branch and to have accumulated a growth in the wood, as shown by the dark shading; as the result of this the uppermost branches *b* have died (as indicated by a lighter shading in the diagram), and the further progress of the

disease downwards is indicated by the arrows, the branches

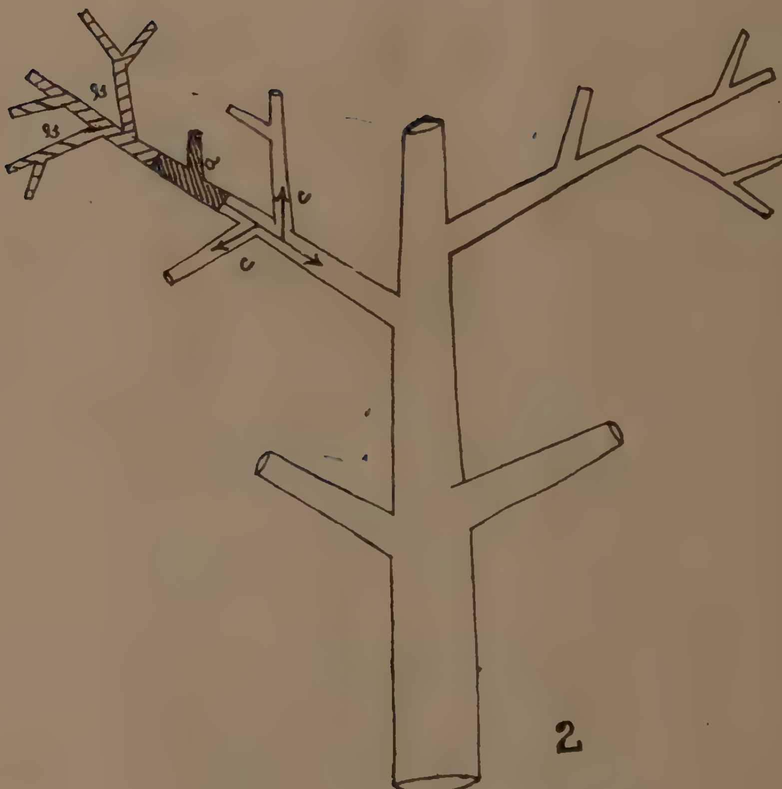

Diagram 2.

c c being the next to die. Diagram 2 represents a similar case, in which the fungus has entered at one of the lateral branches instead of the "leader."

The fungus may enter through a dead or wounded part lower down on the stem. Here it accumulates a

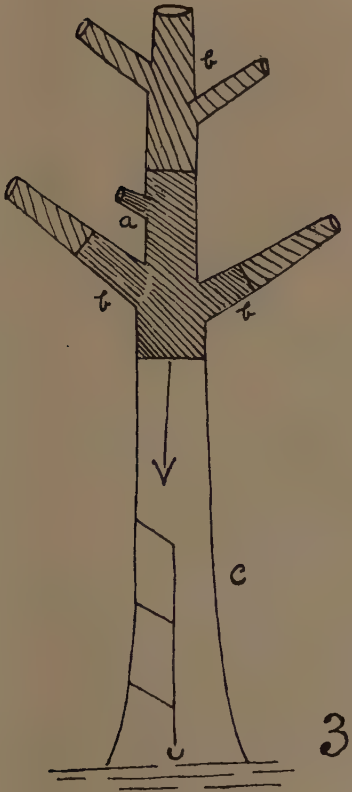

Diagram 3.

growth, as shown at *a* in diagram 3, the resultant effect of which is the death of all of the branches above it, as shown at *b*, the disease then proceeding down the trunk. The

photograph 3 illustrates a case in which the fungus entered low down on the stem, and a broad strip of

Photograph 3.

bark has been removed in order to show the diseased wood. The actual point of entrance is at the scars (broken ends) of two branches shown in the photograph above the

place where the bark has been removed. The death of all three of the branches of the tree seen in the photograph had recently occurred. The death of a large number of branches simultaneously, which occurs when the fungus enters low down on the stem, simulates in appearance the effect of an attack from a root disease; but there is this one important difference, viz. that the parts below are living and continue to yield latex on being tapped, as is indicated at *c* in diagram 3; this is not the case with a root disease.

The above forms of "die-back" are usually met with, the former being more common than the latter. In both cases, however, the symptoms are well-defined, viz. the rapid death of a certain portion of the stem and the subsequent progress of the disease backwards or downwards. In some cases, however, the fungus may enter low down on the stem and may effect the death of the wood slowly; the bark which is external to the area of dead wood dies and the adjacent bark with its cambium makes an attempt to cover over the dead wood, with the result that when the dead bark falls away or is removed a "canker" is exposed to view, *i.e.* an exposed dead area of wood surrounded by a lip of renewing tissue, the product of activity of the cambium. This is a true "canker"—an attempt on the part of the plant to heal a lesion against the action of an organism which tends to keep it open. Such a "canker," resulting from the action of the *Diplodia*, is sometimes, though not frequently met with.

The typical symptoms and progress of the disease have been described above; it remains to describe certain irregularities which sometimes occur. In one case a branch may become infected with the fungus and may die backwards for a certain portion of its length, when an actively growing shoot is produced below the dead part and the dying back ceases. This arrest of the disease has also been met with in seedlings which were infected artificially. Again, a branch may die back to its base and the disease may be checked without proceeding further to the main stem. And thirdly, the fungus may enter through a dead branch, and, instead of accumulating a growth in the wood where it entered, it may proceed down the trunk in a limited area of the wood, with the result that although the fungus may have reached the base of the tree the branches above are not yet dead. The explanation of this is simple and is to the effect that the fungus has not killed off all of the wood at any one part of the trunk; it has not, therefore, at any part of the trunk cut off com-

munication between the roots and branches, the branches still continuing to be fed from below through the remaining living wood. An example of this occurs on a tree at the Experimental Gardens at Kuala Lumpur. Attention was first called to the tree by the entrance of borers through the bark, and the area of infected wood on the trunk was traced by cutting into the dead wood and observing the extent of the grey discolouration due to the fungus.

The time taken for a branch to die varies principally according to its size, the position at which the fungus entered and the general condition of health of the plant. Observations have shown that a branch of 2 inches in diameter at its thickest end takes about 8 or 9 weeks to die back from near the tip in an average case. Seedlings, five months of age, were killed in approximately three weeks after inoculation; seedlings, one year old, were killed in about 8 or 9 weeks after inoculation under favourable conditions for growth of the fungus. The time—rate of progress of the disease allows of ample time for observation.

Passing from the external symptoms of disease and death to the appearance presented by the diseased tissues, it will be necessary to describe in some detail the effect of the fungus on the wood and bark and finally the nature of the fruits of the fungus and the appearance of the spores, since these, coupled with the general symptoms and progress of disease, form the means by which the die-back disease is identified.

The wood of an attacked branch shows the symptoms of disease best. As the growth of the fungus proceeds, the wood becomes of grey colour, which is evident on removing the superficial layers of the wood and exposing a cleanly cut surface with a knife. This discolouration may be more evident in the wood of one side of a branch than of another, but it never occurs in streaks and lines as is common in the case of the wood when attacked by another wound fungus, viz. *Eutypa caulivora;* in other words, the effect which is due to the *Diplodia* is a homogeneous grey or dark grey colour in the wood. This is a most important symptom of diagnosis and one that every cultivator should become acquainted with. The death of the wood is always more evident than that of the outer tissues. As the diseased wood is traced downwards, a good line of demarcation can be found between dead and dying tissue; a point is reached where the dark colour of the wood ceases and a brown discolouration becomes evident for a few inches lower

down, beneath which the wood is healthy. The accompany-

Photograph 4.

ing photograph illustrates the line of demarcation between dead and dying tissue in the main axis of a tree which is affected with the disease; the bark has been removed down as far as the cut end of one of the large branches at the fork, and the line of demarcation between dead and dying tissue in the wood is well shown. It has been found by an examination of the wood of an attacked branch that the fungus extends for a distance of a few inches below where the wood is discoloured. It is, therefore, important in amputating a diseased part to cut down to where the wood is healthy and to remove another six inches of the part below this.

Between the wood and bark there is a black mass which was originally the layer of living cambium; this forms a resort for insects of various kinds.

The bark becomes usually of a greyish colour, and, as the disease proceeds, it cracks and peels off, thus exposing the black mass adherent to the surface of the wood.

A brief reference may be made to "bleeding," which has been put forward by some as an indication of the disease. "Bleeding" may occur from various causes, of which the two commoner are the bending of the branches by wind and the pecking of the branches by birds. Parts which are affected with the die-back disease may bleed, but the "bleeding" appears to have little or no connexion with the disease.

After the attacked part of the plant is dead, the fruits of the fungus make their appearance. They take the form of minute black points which burst through the bark and come to the surface; individually they are not visible to the naked eye, but they are usually aggregated in masses in which form they are easily visible to the unaided eye. From these fruits, which are "spore-cases," the spores of the fungus are extruded; and if they are under damp conditions, they may be extruded in large numbers so as to form a sooty black covering on the bark.

Before concluding the symptoms which serve for identification of the disease, it will be necessary to draw attention to some effects which are liable to be confused with the die-back disease. Sometimes trees shed their leaves on one or on all of the branches at irregular periods, *i.e.* at such periods as do not correspond with periods of drought. It not infrequently happens that leafless branches are mistaken for cases of die-back disease, and there has been a tendency to remove all leafless branches whether they are living or dead. It is only necessary to send a coolie up a tree in order to ascertain whether branches are living. And frequently, providing that the tree is not too large, it is possible to ascertain whether branches are living by shaking the trunk of the tree and observing whether the branches bend easily or not; living branches are flexible, while dead branches only bend with some difficulty. The partial or general defoliation of the trees is due to drought, to flooding of the land, to the presence of a peaty bottom soil or to an impervious clay bottom in the subsoil, and to other causes not easily understood at the present state of our knowledge. In some cases the phenomenon appears to precede the period of flowering. The reckless removal of leafless branches must, therefore, be guarded against. Again, as the trees grow older and expand above, the lower branches become shaded and die.

Usually, their leaves become yellow and fall, and they die slowly. During the present dry season, however, such lower branches have been dying off rapidly, their death apparently being accelerated by the dry weather. These branches are not killed by the *Diplodia,* but they form a source of entrance for the *Diplodia* when they are dead. They will be referred to in the section on treatment of the disease.

The die-back disease usually occurs on plantations among individual trees scattered here and there. It seldom occurs on groups of trees; but cases have been recorded in which groups of ten or fifteen trees have been affected simultaneously. Among older trees it is more common, there being in old trees a large number of points of entrance available for the fungus, more especially where pruning is not done and where excessive tapping, close planting and bad cultivation has resulted in a scanty development of foliage and in a weak appearance generally. Among very young rubber the disease is also fairly common, the cut ends of the stumps affording an easy means of entrance for the fungus. Among unhealthy plants generally it is not only more common, but it also does more damage.

Finally, cases have been recorded in which the fungus has entered through the cut ends of roots of stumps which had been lifted for planting. In such cases the fungus gives rise to the ordinary symptoms of a root disease. The occurrence is, however, not common.

SPREAD AND SOURCES OF INFECTION.

In describing the fruits of the fungus above, mention was made of the spores which are extruded from the small black masses on the bark of the affected branches. The spores are minute bodies (about 1/1000 of an inch in diameter) and function as seeds. They are distributed by the wind and are carried by insects which enter the diseased branches; they thus serve to propagate the disease. A spore germinating on a dead part or dead surface of a branch reproduces the mycelium of the fungus which grows in the dead part or surface and spreads to the healthy adjacent parts, thus reproducing the disease. The spores are produced in myriads on dead parts of plants of many kinds, and more especially on those which are recently dead.

Any dead surface, whether it be a dead branch, a wounded branch or a wound on the trunk, affords a means of entrance for the fungus which is itself incapable of entering through a healthy part. It has been shown that at very small wounds, such as would be produced by small insects, the fungus cannot effect an entrance. In other words, it requires a dead surface of appreciable size on which it can accumulate a growth before spreading to the healthy parts.

The wounds and other sources of entrance for the fungus which occur usually on Para rubber plants will be given in some detail thus:—In the planting out of stumps the cut end of each stump presents a wounded surface. When growth commences again, a shoot arises from below this cut end and the portion of the stem above the point of origin of the young shoot dies; this dead part affords a means of entrance for the fungus. "Topping" exposes a wounded surface. Pruning, either "thumb-nail" or the removal of small or large branches, leaves a wound. Other wounds occur, such as those produced by wind, lightning, by animals and by man.

As the trees grow older, the lower branches which have no ready access to the light die; and it is not uncommon to find that the fungus has entered through them and is proceeding to the trunk of the tree.

The highest branches, usually consisting of the end of the main axis of the tree, sometimes become leafless and die. This is commonly met with on badly drained soil, and it appears in other cases to be connected with unsuitable soil conditions or with poverty of the soil. In some cases wind causes a defoliation of the top shoots. Such dead branches as these afford the fungus a means of entrance.

The "pink disease" produces a disintegration of the bark of the stem and exposes the wood beneath. Attacks by the *Diplodia* frequently follow on attacks from the "pink disease."

TREATMENT.

The fungus has been shown to be capable of propagating itself on dead parts of many plants, thus giving rise to spores which serve to spread the disease. The diseased parts of plants and also the dead plant which remains furnish the spores for spread of the disease. These should, therefore, be burnt. Care must be taken to avoid scorching the neighbouring trees, and the fires made must, therefore, be small and must be under control. It is also necessary,

when branches are being burnt, to avoid setting fire to the surrounding masses of leaves and brushwood in dry weather. During a drought a large quantity of the dead branches may be burnt in the drains which in many places are free from water. Dead parts of other plants which are growing along with the rubber, such as coffee and coconuts, should also be burnt. Such a method of sanitation reduces the spore production of the fungus.

The fungus causes greater damage to unhealthy trees than to healthy ones. Attempts should, therefore, be made to ensure a vigorous growth of the plant. By careful pruning and by avoiding close planting, a good access of light should be obtained to all of the branches. By good subsoil drainage the excess of water in the soil and subsoil should be got rid of. The size of drains and their distance apart depends on the nature of the soil; in cases where the land is particularly heavy and lowlying, drains may be made even as close as 1 chain apart. All drains should possess a good gradient and should have a good access to the main drain, care being taken that there is an appreciable flow in the main drain and a good outlet to it. If the land requires "contour" drains, these should be properly marked out with a "tracer" before they are dug. Heavy soils may be reduced and peaty soils neutralised by an application of lime. The lime should be obtained in the form of quick lime, should be placed on the field in heaps and allowed to slake naturally, when it should be spread over the land and turned in. It should not be allowed to become overslaked and pasty. A common application of lime is 15 pikuls per acre; but, for soils rich in organic matter larger quantities may be used.

As a preventive means all wounds should be tarred. The correct tar to use is ordinary coal tar. There has been in some cases in this country an objection raised to the use of coal tar on the pretext that it injures the plant; this objection is entirely unfounded and can only have been imagined or else have arisen through careless application. Before tarring a wound it is necessary to ascertain that the exposed wood is surrounded by bark tissue which is capable of renewing, *i.e.* which is alive. The exposed surface of the wood only should be tarred; the tar should not be allowed to run down the sides of the branch or trunk. The tar should be used cold and should be applied by means of a brush and not with any or every kind of bits of wood. It was previously recommended that the tar should be warmed slightly before using it; this is more advantageous,

but, since warmed tar runs more easily it is, perhaps, best for the coolie to use the tar cold. A smooth surface should be procured for tarring, and, if it is wet, it should be allowed to dry before the tar is applied. Small wounds only require to be tarred once, but in larger wounds a second tarring is advisable sometime after the first.

Care should be taken to tar the cut ends of "stumps" used for planting; and, in order to avoid infection through the broken ends of the roots of "stumps" when they are lifted from the nurseries, it is advisable to expose the roots for as short a time as possible.

Pruning should be carried out systematically and carefully. Superfluous branches at the fork of older trees should be removed in order to allow of a better expansion of the parts above and to get rid of such smaller branches as will eventually die through being shaded and will thus allow the fungus to effect an entrance into the plant. Where the topmost branches are withering it is best to leave them alone and to induce a more vigorous growth by remedying the deficiency in the soil, if this be the cause of defoliation.

All diseased branches should be removed. The indication of the extent of the disease is furnished by the discolouration of the wood. In removing a diseased part it is necessary to cut back to a point where the wood is not discoloured and then to remove another six inches of the part below this. A sloping surface should always be left after removal. Larger branches should be removed by means of a saw. In removing a large branch it will be found advantageous to make more than one cut; first, a cut should be made eight or ten inches from the trunk from below upwards and should go half-way through the branch; then a cut should be made two inches further from the trunk from above downwards and should go through the branch. Finally, the stub should be sawn off flush with the trunk. Stubs should never be left.

"Topping" and deep tapping with consequent exposure of the wood, should always be avoided.

Care should be taken in burning off timber to avoid scorching the neighbouring trees as far as is possible.

This concludes the account of the "die-back disease of *Hevea*," in which the occurrence of the fungus, the symptoms and spread of the disease and the preventive and curative measures to be adopted for its treatment are given in some detail.

A NOTE ON THE LEAF DISEASES OF PARA RUBBER.

Little or no attention has hitherto been paid to the leaf diseases of *Hevea* in the Federated Malay States, and it is for this reason proposed to give a brief summary of the leaf diseases hitherto described on Para rubber from different parts of the world and to call special attention to those which have been found to occur in Malaya.

The leaf diseases of *Hevea* can scarcely be recognised at the present moment as being of any appreciable economic importance. The fungi which affect the leaves of the plant, although they number a dozen, only occur in small quantity; and even in the nurseries, where leaf fungi are wont to cause greater damage than among older plants, the number of affected plants has hitherto been small. Further, in reviewing the leaf diseases of *Hevea,* one factor must be clearly emphasised, and that is the capacity of the plant for shedding and renewing its leaves at any period and with great facility; it is, therefore, easy to observe the difference in the damage caused by a leaf fungus on a leaf of *Hevea,* which can be cast off at any period and with little appreciable loss to the plant, and on a leaf of coffee which is possessed of a comparatively long life and whose loss to the plant can only be remedied with some difficulty. For this reason the leaf fungi which are parasitic on *Hevea* must increase in enormous proportions before they can produce any appreciable effect on the plant.

Hitherto seven fungi have been reported to affect the leaves of *Hevea* in the East and five in the Amazon district. Since all of them produce either a spotting or yellowing of the leaves, they cannot be differentiated by the term "leaf spot" and "yellowing leaf" fungus; they will therefore, have to be called by their specific names.

Pestalozzia Guepini is the commonest leaf fungus in the East. It is the same fungus as causes the "grey blight" of the tea plant and it may therefore be expected to occur in larger quantities in districts where tea is cultivated along with *Hevea.* The fungus produces semi-transparent spots bounded by a narrow reddish brown line. Its action appears to be local and confined to the spots. It is said to kill the seedling when it attacks it at the "collar"; but

hitherto it has not been recorded to attack the stems of the seedlings in the Federated Malay States. On the stems of seedlings in Ceylon it is said to produce a diseased patch which takes the form of a white ring bordered by a narrow reddish brown line.

Pestalozzia Palmarum, a fungus which causes a "leaf spot" of palms throughout the Tropics and which is well known on coconuts in this country, is also said to attack the leaves of *Hevea* in the East; but, it has not been recorded on *Hevea* in the Federated Malay States and its parasitism on *Hevea* is doubtful. Attempts are being made at the present time to inoculate with it. It would appear to be not unlikely that it has been confused with the other species above, *P. Guepini.*

Phyllosticta Heveae was first described from Java and has been found to occur in Ceylon and in Malaya. It produces brownish spots situated usually at the extremities of the leaves.

Helminthosporium Heveae and *Gloeosporium elasticae* have been recorded from Ceylon, but there is hitherto no record of their occurrence in Malaya; in Ceylon also, *Gloeosporium brunneum* and *Colletotrichum Heveae* have been reported to cause the yellowing and dropping of the first two leaves of seedlings. In the Amazon district five leaf fungi are said to occur on *Hevea,* but only one, *Ophiobolus Heveae,* is regarded as being of any importance.

The leaf fungi in Malaya are more commonly met with in the nursery, and it has been shown that not only the fungi, but also the insects, which attack the leaves and shoots of seedlings in the nursery can be effectively warded off by the application of a boiled lime-sulphur mixture. The preparation of the mixture is given in the "Agricultural Bulletin of the Straits Settlements and Federated Malay States," April 1911, p. 114. The mixture should be applied by means of a "Vermorel Eclair" Sprayer, and, by reason of the action of the sulphur contained in the mixture on the reservoir of the machine if it be made of copper, a *tin-lined* "Eclair" must be used. These are supplied by Messrs. A. C. Harper & Co., Kuala Lumpur, and by The Borneo Company, Singapore.

A measure for the control of leaf diseases throughout this country, and one which might well be carried out, is to collect and burn in small heaps all of the leaves which have fallen as soon as the annual period of wintering has commenced. Such a measure would considerably reduce the spore production of the leaf fungi; for such a measure

to have its full effect, however, it would be necessary for everyone systematically to collect and burn as many of the fallen leaves as possible. There appears to be no reason why it should be a costly proceeding and it is hoped that the suggestion will be carefully considered by the planting community.

Allements & Federated Malay States, April 19

With the compliments of the author.

BROWN ROOT DISEASE OF PARA RUBBER.

(Hymenochaete noxia, Berk*).*

BY KEITH BANCROFT, B.A., ASSISTANT MYCOLOGIST, F.M.S.

A root disease of Para Rubber which has been for some time known in Ceylon under the name of "brown root disease," † has been recently brought to the notice of the Department of Agriculture, F.M.S.

The fungus, *Hymenochaete noxia*, the cause of the disease, was discovered by Rev. T. Powell in Samoa in 1875, on a species of *Artocarpus*. In 1905, it was reported in Ceylon on *Hevea*, Tea, Dadap, Cacao, *Castilloa elastica* and Caravonica Cotton; since then it has also been found on Camphor (*Cinnamomum Camphora*), *Cinnamomum Cassia*, Cacao and *Brunfelsia americana*. It is said to be the commonest root disease of *Hevea* in Ceylon. In the early part of 1910, specimens of the fungus were sent to Kew from West Africa, where the fungus was said to be doing some considerable damage to Cacao. The fungus has also been recorded in New Guinea.

A disease, which, from its symptoms, appears to be the "brown root disease," was mentioned by Mr. Gallagher in Bulletin No. 2, 1909, Department of Agriculture, F.M.S., as occurring in this country on *Hevea* and on Camphor; the fungus was, however, not identified. Mr. Ridley ‡ mentions the report of the disease from Apia and states that he has observed a species of *Hymenochaete* on Para Rubber in the Malay States.

The fungus was first recorded by the author on roots of Camphor (*Cinnamomum Camphora* in the Experimental Gardens at Kuala Lumpur, where a number of plants were attacked. More recently it has been reported on *Hevea* from some estates in Negri Sembilan. In the plantations it appeared to be fairly common in certain areas although on the whole in this country it is by no means so common as the disease caused by *Fomes semitostus*.

Symptoms.

When a tree is attacked the symptoms above ground do not differ in any respect from those of the root disease caused by *Fomes semitostus* or from the ordinary symptoms of root disease generally, i.e., the leaves wither and death occurs rather suddenly. An examination of the roots shows the presence of well-marked symptoms which characterise the disease. They are encrusted with a mass of earth and small stones which are cemented to the surface of the roots by the mycelium of the fungus. This can be found to occur more especially on the tap root. The surface of the roots becomes dark brown and almost black; for this reason the disease is known to the coolie as "sakit hitam."

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† Petch: Circulars and Agricultural Journal, Royal Botanic Gardens, Ceylon, Vol. V., No. 6, 1910.

‡ Ridley: Agricultural Bulletin, S.S. and F.M.S., July,

The mycelium takes the form of light brown threads when young, and becomes later expanded over the surface of the root in the form of sheets, and collected here and there into nodules. The sheets of mycelium are dark in colour on the surface, and white or light brown beneath.

In Ceylon the progress of the disease is said to be very slow, and observations which have been made in this country up to the present confirm this. In some cases where the tap root was attacked, it has been found that adventitious roots have arisen, and having grown vertically downwards have taken the place of the tap root,—a further indication of the slow progress of the disease. At each centre of infection one or two trees only have been found to be diseased, and each case has been found to be the result of a separate infection.

The mycelium appears to be incapable of spreading independently through the soil, and infection can, therefore, only occur by the contact of a diseased with a healthy root. The growth of the mycelium is, however, so slow that the attacked tree is dead some time before the fungus has spread to the adjacent trees. Where two adjacent trees are attacked simultaneously, each has become infected separately from one or more jungle stumps. If the dead tree be left standing for some time the disease may spread to the adjacent trees. To illustrate the slow progress of the disease Mr. Petch, Mycologist, Royal Botanic Gardens, Ceylon, cites the following instance:—" *Hevea* was planted, 14 feet apart, in single line round the boundary of an old-established Cacao estate. When the trees were eight years old, one of them died, from brown root disease as was subsequently discovered. The tree was left standing and allowed to decay. Two years later the next tree in the line died and was likewise left to decay. After a further two years had elapsed, the next tree in the same direction along the line failed to recover after wintering, and was evidently dying; and an examination of this tree and the two old decaying stumps proved that they had all been killed by brown root disease."

In Samoa and in West Africa, the disease appears to be more serious than either in Ceylon or in this country. When reported at Kew from West Africa the disease was said to spread somewhat rapidly, and in Samoa it has been said to cause considerable injury to breadfruit (*Artocarpus incisa.*)

The youngest age of an attacked tree which has been recorded in this country is three years.

Spread.

From what is known of the fungus it is unquestionably a jungle product, and, from the long list of cultivated plants which it attacks, one might infer that in the jungle it does not confine itself to any small number of hosts.

From observations which have been made up to the present time in this country each case of infection has been referable to the presence of a jungle stump.

The fungus does not apparently fruit in any abundance in this country; in fact, hitherto it has only been possible to find a single fruit, on camphor, and this a badly developed specimen. The fruit takes the form of a velvety, brown, in crusted mass on the base of the plant at the collar. In specimens of the fungus which have been examined on Cacao by the author, the brown mass was observed to ring the stem at the collar for a distance of about three inches. In Samoa and in West Africa, there appears to have been no difficulty in obtaining the fruits of the fungus. The scarcity of fruits in this country would lead one to infer that the propagation of the disease by means of spores is scarcely worthy of serious consideration.

Treatment.

When a tree dies it is necessary to remove it with as much of the roots as possible and burn them.

Old stumps with their roots should also be removed from the infected area and burnt.

Trenching is unnecessary; and the application of quicklime may be dispensed with, providing that all of the diseased roots have been removed.

In each centre of infection the lateral roots of trees adjacent to the dead tree should be examined and any which are diseased should be cut off to a point where they are healthy, and the diseased portion removed and burnt.

There appears to be no reason why replanting should not be done immediately after the area occupied by the diseased tree has been dug over and the wood has been removed.

A DISEASE OF SEEDLINGS OF PALAQUIUM OBLONGIFOLIUM.

(*Laestadia Palaquii n. sp.*)

BY KEITH BANCROFT, B.A., ASSISTANT MYCOLOGIST, F.M.S.

A disease of seedlings of *Palaquium oblongifolium*, Burck., has recently been reported from the nurseries of the Forestry Department at Trolak (Perak) where a large number of seedlings are said to be affected. The plants of *Palaquium oblongifolium* are being cultivated along with *Balanocarpus maximus* (Chengal); the latter, however, are not affected.

Symptoms.

When the seedlings are attacked, brown spots appear on the leaves. The spots increase in size and frequently become confluent, so that nearly the whole area of the leaf may become brown. The remaining part of the leaf becomes yellow, and the leaf withers and dies. The death of the leaves is followed by the withering of the young part of the stem, and, finally, by the death of the seedling.

Both young and old leaves may become spotted.

Sometimes, the seedling throws up a new shoot from below. The actual fate of this shoot is unknown.

The Fungus.

Material of all stages of the disease has been forwarded to the Agricultural Department for examination. The tissues of the mesophyll of the leaves are overrun with hyaline, branched, septate hyphae 4 microns in width. On the upper surface of the leaves are produced black perithecia which are not visible to the naked eye. The perithecia are less abundant on the under surface of the leaves; they are closely associated with the internal mycelium, and when viewed under a lens appear as small black dots; they bear asci without paraphyses, each ascus containing eight ascospores.

The fungus belongs to the genus *Laestadia*, and in its characters is sufficiently distinct from any other species of *Laestadia* to be designated a new species. It has been named *L. Palaquii*, n. sp.

Other species of the genus *Laestadia* which have been recorded in the East are:—*L. Theae*, Rac., described on tea in Java, which the new species resembles somewhat in the characters of perithecia and asci, but from which it differs markedly in the nature of the spots and mode of arrangement of the perithecia; *L. Camilleae*, Cooke, described on *Camillea Thea* in Johore; *L. Oxalidis*, Sacc., on *Oxalis corniculata* in Ceylon; *L. Pertusa*, Sacc., on *Dioscorea tomentosa* in Ceylon; and *L. Caesalpiniae* Pat. on species of *Caesalpinia* in Java.

The best known case of parasitism of the genus is that *L. Bidwellii* on the Vine in the United States of America and in France; this fungus which causes the "black rot" is the most dreaded fungus parasite on the Vine in the United States.

Spread of the Disease.

It is not improbable that the rapid spread of the disease is brought about by the presence of a pycnidial form of the nature of a *Phoma*. A small pycnidial form has appeared on the spots previously to the development of the perithecia and has been identified as a *Phoma*; and a careful examination of material is being made for the purpose of demonstrating the connexion between this and the ascigerous fungus.

Shewing the threads of the Fungus on the stem and leaves of Camphor.

Treatment.

It has been recommended that all of the dead and badly diseased seedlings be collected and burnt to prevent the spread of the disease by the spores produced on diseased parts.

A better access of light to the seedlings has also been advised.

For the control of the disease it has been recommended that the seedlings in diseased areas be sprayed with Bordeaux Mixture, the 6—4—50 formula being employed for preparation of the mixture, and the mixture being applied as a preventitive.

A diagnosis of the fungus is appended :—

Maculis amphigenis, subrotundatis vel irregularibus, brunneis; perithecüs saepius epiphyllis, sparsis, initio epidermide velatis, nigris, membranaceis, globoso-depressis, 90–100 microns diamr., ostiolo obsoleto; ascis clavulatis, sessilibus, aparaphysatis, octosporis, 32—36 × 8 microns; sporis oblongis, utrinque obtusis, continuis, hyalinis, subdistichis, 10—12 × 3.5—4 microns.

A THREAD-BLIGHT ON PARA RUBBER, CAMPHOR, Etc.

BY KEITH BANCROFT, B.A., ASSISTANT MYCOLOGIST, F.M.S.

A disease which from its symptoms may well be called a "thread-blight" has recently made its appearance on Para rubber and camphor (*Cinnamomum Camphora*). The disease was first recorded on camphor, seven years old, in the Experimental Gardens at Batu Tiga (Selangor) where four adjacent plants were affected. Within a few days from this it was reported on Para rubber trees on an Estate in Negri Sembilan. The affected Para rubber trees were approximately seven or eight years old, were near to each other and were situated close to a belt of virgin jungle.

Symptoms.

When a tree is attacked the leaves on the younger parts wither and hang down and may become matted together in dense masses. The younger twigs also wither and the young buds die. Finally, as the disease progresses many of the leaves fall.

A close inspection shows the presence of white strands on the affected branches. These are rhizomorphic strands and constitute the vegetative portion of the fungus. On older parts the strands are usually thin ('1 c.m) and frequently pursue a zig-zag course, being seldom branched. As they pass upwards to the younger branches they frequently become thicker (as much as '2—'25 cm. in diameter) and are repeatedly branched. Here and there a strand may become frayed out on the surface of a branch and pass into fine fibrils, becoming lost to the naked eye. A branch from a strand passes along to a younger twig and growing along the under side of a petiole of a leaf reaches the under surface of the lamina; here it branches repeatedly and spreads itself over the surface of the leaf until the whole of the under surface of the leaf is covered with a white mass of fine fibrils.

Here and there occur structures which are larger than the strands, have an irregular outline and frequently form starting points for the origin of fresh strands.

When a strand comes into contact with an irregularity or roughness on the surface of a branch, or when it reaches a young bud, it produces a dense growth. This also occurs when the mycelium of one leaf comes into contact with another leaf.

The younger parts of the branches suffer severely from the presence of the fungus.

So efficient is the means of propagation by the strands that when a branch is infected all of the young parts become affected by the strands.

The Fungus.

Each strand consists of a central portion or core which is made up of hyphae running longitudinally. These hyphae are hyaline, measure 4-5 microns in diameter and are septate at long intervals; they are sparingly branched and contain no refractive cell-contents. Branches from the innermost hyphae first arise at right angles to the parent hyphae and then, bending around, pursue a longitudinal course. Branches from the outermost hyphae do not for the most part run longitudinally, but project from the central core and give the strand its soft and shiny appearance.

The larger structures of irregular outline which occur here and there on a strand are composed of dense masses of hyphae and may be looked upon as undifferentiated sclerotia.

When an affected leaf is placed in a moist chamber in contact with healthy leaves the white mycelium first accumulates a dense, fluffy growth and then spreads to the unaffected leaves.

Spread.

By virtue of the superficial strands the fungus possesses an excellent means of propagation. A careful search has failed to demonstrate the presence of any spore-bearing organs, nor were these developed when the mycelium was placed in a moist chamber and kept for several weeks. It may, therefore, be concluded that the primary means of propagation is by the vegetative strands and that this is accompanied by a suppression or partial suppression of the spore-bearing organs.

It has been possible to trace the mode in which infection occurs in the field. Here and there infected leaves have been blown by wind and lodged against a branch. The mycelium on the leaf accumulates a dense growth by which the leaf is made to adhere closely to the branch. From this point strands arise and traverse the branch in all directions. Infection was also seen to pass from a branch on an infected tree to a healthy tree through the leaves of adjacent branches being in contact with each other. Again, in the case of two camphor plants, the strands were seen to pass from fallen leaves on the ground up the branches and to reach the younger twigs.

The mycelium of the fungus is very sensitive to moisture and to contact. The former is illustrated by the dense growth which is accumulated when the mycelium is placed in a moist chamber and when the mycelium reaches the more shaded and damper portions of a branch. The latter is shown by the rapid growth of the mycelium where two leaves or twigs come into contact with each other or where an infected leaf lodges against a branch.

Distribution.

Judging by analogy with other "thread-blights" one may well expect that this fungus comes in from the jungle; and the close proximity of the plants hitherto attacked to the jungle is in favour of this conclusion. In neither case, however, was it possible to make an examination of the jungle adjacent to the infected area.

The fungus on *Hevea* and the one on camphor were, as far as can be ascertained by an examination of sterile mycelium, identical with each other. A fungus which is similar in all respects to the one on Hevea has also been found on Guava (*Psidium Guyava*). From what is known of fungi of this nature it is improbable that in the jungle it should confine itself to even a few different plants.

Other Thread-Blights

Several fungi of a similar nature have been described from different parts of the world. The best known of these is, perhaps, the

"thread-blight" of tea, *Stilbum nanum*, Massee, in Southern India and Ceylon. A "leaf-blight" of coffee in Porto Rico in 1904 has been attributed to an unidentified species of *Sclerotium*. A "thread-blight" of cacao was described from the West Indies in 1906. And recently a disease of pomaceous fruits known as "hypochnose" has been reported in North Carolina, U.S.A., and has been attributed to *Hypochnus ochroleucus*, Noack.

Indentification of the Fungus.

Hitherto it has not been possible to identify the fungus on *Hevea* and camphor owing to the absence of spore-bearing organs, although a number of specimens have been carefully examined.

Such an occurrence is not unusual in fungi of this nature; the "thread-blight" of tea and "hypochnose" of pomaceous fruits were long known before any fruiting organs were found, while the fungi causing the "thread-blight" on cacao and the "leaf-blight" of coffee have yet not been identified.

Clamp-connexions can be frequently found in the mycelium on the leaves; they occur less frequently in the strands on the twigs. From the presence of these organs the fungus is concluded to be a *Basidiomycete*. From what is known of mycelium of this nature, one might expect the fungus to belong either to the genus *Hypochnus* or to the genus *Corticium*.

Treatment.

The means by which the disease is spread necessitates the sanitation of diseased areas. All fallen leaves and twigs under affected trees should be scraped or gathered into heaps and burnt. The heaps should be small in order to avoid scorching of the surrounding trees.

The diseased trees may be cured by pruning the affected parts. The damage done by the fungus is confined to the younger branches. Threads are seldom met with on the old parts of large branches, and it is only necessary to remove those parts which actually bear the fungus, so that, providing the disease is observed in its early stages, the loss arising from pruning is not great. All prunings should be carefully collected and burnt.

In the case of the *Hevea* trees which were attacked by the fungus the disease was not sufficiently abundant to warrant the application of any preventive treatment to adjacent trees. The disease on camphor was controlled by removing two badly affected plants, pruning the remainder and cleansing the area of fallen leaves and twigs.

In other parts of the world, outbreaks of the disease have been controlled by the application of a lime-sulphur wash of which it will

be advisable to give here the formula and method of preparation. Into an earthenware vessel* ten pounds of fresh quicklime are placed, and three or four gallons of hot water added. The lime is allowed to slake for a short time and eight pounds of sulphur are added. The heat of slaking of the lime should be sufficient to boil the mixture if the lime is fresh. The mixture is stirred and allowed to change to a yellowish brown colour, when it is made up with cold water to 50 gallons. The mixture is then strained through a sieve or piece of fine sacking, care being taken to work through the meshes any sulphur which remains over. The mixture is now ready for use and is applied by means of a spray.

The above is the method of preparation of what is known as the self-boiled lime-sulphur mixture. Owing to the difficulty in obtaining good quicklime in this country it will scarcely be possible to prepare the self-boiled mixture. It will, therefore, be necessary to make the mixture up to 50 gallons using a zinc-lined** vessel and to boil it for half an hour over an open fire, when the necessary chemical reaction between the lime and sulphur will take place.

The best sprayer for ordinary use in this country is the "Vermorel Eclair." These are stocked by the Borneo Company, Ltd., Singapore, and by Messrs. A. C. Harper & Co., Kuala Lumpur, Klang, etc. The price of each is about $25. An "Eclair" sprayer can reach a height of ten feet, so that it can be readily used in young Rubber, Coffee, Camphor, etc. For the purpose of spraying older trees a more powerful machine is required. The "Eclair No. 3," fitted with accessories, can reach a height of twenty feet. But it is advisable to have a more powerful sprayer and, for this purpose, a vermorel "Cascade" sprayer has been ordered by the Department of Agriculture, and arrangements are being made to have it stocked in this country. It reaches a vertical height of forty-five feet. The reservoir of "Vermorel" Spraying machines is usually made of copper, but for use with reagents which react chemically with copper, such as the lime-sulphur mixture above, tin-lined reservoirs are supplied.

From what is known of the fungus at the present time it is very improbable that the spread of the disease by spores occurs at all readily. The propagation of the fungus by means of the white mycelium alone requires consideration. For this reason the distance from which infection can spread by wind-blown mycelium is necessarily small. In view of this one might anticipate that only areas which are within a comparatively short distance of jungle are liable to be infected primarily. Repeated outbreaks of the disease in areas adjacent to the jungle will, therefore, necessitate the felling and burning of a portion of the adjacent jungle.

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* A Shanghai jar serves the purpose well.

** An old latex cart will do.

Sonderabdruck aus der „Zeitschrift für Pflanzenkrankheiten“,
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(*Verlag von Eugen Ulmer in Stuttgart.*)

Die Pilze von Hevea brasiliensis (Para Kautschuk).

Von T. Petch (Mycologist to the Government of Ceylon).

Die bemerkenswerteste Erscheinung in der tropischen Landwirtschaft ist augenblicklich die Steigerung in der Kultur der Kautschuk-Pflanzen, besonders des Para-Kautschukbaums, der *Hevea brasiliensis*. 1875 wurden Samen von diesem Baume im Botanischen Garten von Kew gewonnen, und im folgenden Jahre wurden junge Pflänzchen an die Botanischen Gärten von Ceylon und Singapore gesendet. Von 1884 an trugen die Bäume in Ceylon Samen; da aber der Preis des Kautschuks damals sehr niedrig war und andere Kulturen höheren Gewinn versprachen, war nur wenig Nachfrage darnach. Aber von 1898 an stieg der Preis des Kautschuks, und die Kultur fing an, außerordentlich lohnend zu werden. Der Anbau der Kautschukpflanzen nahm rasch eine große Ausdehnung an und beträgt gegenwärtig ungefähr 120 000 Acker in Ceylon, 100 000 in den Vereinigten Malayischen Staaten, außer großen Flächen in Java, Borneo, Burmah und anderen Ländern. Sämtliche Pflanzen stammen von Samen aus Ceylon und Singapore.

[1]) J. Wiesner, Der Lichtgenuß der Pflanzen. Leipzig 1907. S. 235.

Anfangs wurden die Bäume dicht, acht bis zehn Fuß auseinander gepflanzt; jetzt hat man dies als falsch aufgegeben und hält eine Pflanzweite von 15 Fuß für das Minimum. Einige Ländereien sind in 30 Fuß breiten Reihen bepflanzt, die Bäume 10 Fuß auseinander. Der Samen wird im August und September geerntet und in Baumschulen ausgesät. Er ist von einer spröden, ungefähr 1 mm dicken Schale umschlossen. Um die Mikropyle herum ist jedoch eine dünnere Zone, etwa 4 mm im Durchmesser, die nur von einer feinen Haut bedeckt ist. Infolge des durch diese dünne Zone bedingten Austrocknens verliert das Samenkorn bald seine Keimfähigkeit. Es ist daher schwierig, die Samen vollwertig auf weite Entfernungen zu verschicken. Die Pflanzen bleiben ein bis zwei Jahre in der Baumschule; dann werden sie herausgehoben, bis auf etwa zwei Fuß Höhe zurückgeschnitten und in das Feld ausgepflanzt. Solche Pflanzen werden „stumps" (Stümpfe) genannt. Zuweilen werden die Samen einzeln in kleine Körbchen ausgesät und die Pflanzen werden dann unbeschnitten ausgepflanzt. In anderen Fällen wird der Same auf dem Felde ausgesät, gleich in der richtigen Pflanzweite („seed at stake" Standexemplare); aber die jungen Sämlinge werden häufig von Stachelschweinen, Schweinen, Ratten u. a. zerstört. Sämtliche Tiere, selbst Kühe, scheinen Geschmack an den jungen *Hevea*-Pflanzen zu finden. Die Bäume werden angezapft, wenn sie drei Fuß hoch über dem Boden 18 Zoll Umfang haben. In der Regel ist das im vierten oder fünften Jahre nach dem Verpflanzen der Fall. Es sind verschiedene Zapfmethoden im Gebrauch, die alle mit der Tatsache rechnen, daß die Menge des Milchsaftes, der durch wiederholtes Öffnen der ursprünglichen Schnitte gewonnen wird, bis zum 14. Anzapfen zunimmt. So wird, nachdem der erste Schnitt gemacht worden ist, durch den zweiten, ein oder zwei Tage darnach, einfach eine dünne Haut von dem untern Rande der Wunde fortgenommen. Da dieses Verfahren zuweilen mehrere Monate lang fortgesetzt wird, so wird ein großes Stück der Rinde beschädigt, und es ist unmöglich, während des Zapfens die Wunde mit Pilzmitteln zu behandeln. In dieser Hinsicht unterscheidet sich *Hevea* wesentlich von *Castilloa*, bei der der ganze Milchsaft durch den ersten Schnitt gewonnen wird. Indessen heilt sich die Wunde durch Bildung neuer Rinde von oben her aus, und bis jetzt sind Pilzbeschädigungen auf der Wunde so selten vorgekommen, daß man ihnen gar keine Beachtung schenkt.

Blatt-Krankheiten.

Es kommen zur Zeit keine ernstlichen Blattkrankheiten bei *Hevea brasiliensis* vor, wenn schon zahlreiche parasitische Pilze auf den Blättern erwähnt werden. Die meisten sind auf Baumschulpflanzen

gefunden worden. Man muß sich dabei vergegenwärtigen, daß die jungen Sämlinge stets beschattet werden; in Ceylon werden die Beete vor allzu starkem Sonnenlicht und Regen durch Bedecken mit gefalteten Kokosnußblättern geschützt, die ungefähr zwei Fuß hoch über der Erde angebracht werden. Die Blätter der jungen Pflanzen sind sehr zart und wenn der Regen oder die Sonnenstrahlen durch Lücken in der Schattendecke dringen, leiden sie schwer dadurch. Die Blätter der an den Ecken des Beetes stehenden Sämlinge werden stets beschädigt und weisen große, weiße, trockene Flecke auf. Wenn die Schattendecke fortgenommen wird, machen sämtliche Sämlinge häufig einen schwer kranken Eindruck. Das kommt lediglich durch die Wirkung der Sonne und des Regens auf die jungen Blätter. Auf den bleichen Flecken können zahllose saprophytische Pilze gefunden werden, z. B. *Periconia*, *Macrosporium*, *Diplodia* u. a. Es erscheint deshalb fraglich, ob alle die Pilze, die als Parasiten der *Hevea*-Sämlinge erwähnt werden, auch wirklich parasitär sind. Genannt werden:

1. *Helminthosporium Heveae* Petch. Dieser Pilz kommt häufig in Baumschulen vor, wenn die Pflanzen ungefähr 3 Fuß hoch sind. Er verursacht kleine, purpurfarbene Flecke, die allmählich weiß, rund und durchscheinend werden und dann purpurbraun gesäumt sind. Die Flecke haben selten mehr als 5 mm Durchmesser, können aber in großer Zahl auf einem Blatte vorkommen. Die großen Sporen (100—120 × 15—18 μ) sind schon mit einer einfachen Lupe zu erkennen. Der Pilz ist auf älteren Bäumen noch nicht gefunden worden und richtet überhaupt nur so geringen Schaden an, daß eine Bekämpfung nicht für nötig gehalten wird. In Ceylon, Südindien und Malaya gefunden.

2. *Pestalozzia palmarum* Cooke. Kommt häufig auf trockenen, weißen Flecken von Sämlingsblättern vor. Wahrscheinlich meistens nur saprophytisch. In einem Falle verursachte der Pilz durch Befall des Wurzelhalses das Absterben von Sämlingen. Die infizierten Stämme waren von einem weißen, rotbraun geränderten Ringe umschlossen. Diese Spezies, die auf Tee, Kokosnuß- und anderen Palmen, sowie auf Rose und Zimtbaum vorkommt, ist, ausgenommen bei Palmen, immer als *Pestalozzia Guepini* Desm. angesprochen worden. Ceylon.

3. *Gloeosporium Elasticae* Cooke und Massee. Auf Blättern von *Hevea brasiliensis* Buitenzorg (Zimmermann). Auf hellbraunen, unregelmäßigen Flecken auf Blättern von Sämlingen. Ceylon. Koorders (Bull. Algemeen Proefstation, Salatiga, Nr. 3) hält den Pilz für identisch mit *Colletotrichum Ficus* Koorders.

4. *Gloeosporium Heveae* Petch. Auf den Blättern von Sämlingen, die dadurch entblättert werden. Ceylon.

5. *Colletotrichum Heveae* Petch. Auf Blättern von Sämlingen. Ceylon.

6. *Phyllosticta Heveae* Zimm. Auf braunen Blattflecken, besonders an der Spitze, Buitenzorg (Zimmermann). Auch auf Blättern von Sämlingen in Ceylon. Parasitisch?

7. *Phyllachora Huberi* P. Henn. Auf Blättern von Sämlingen. Para, Manaos u. s. w. (P. Hennings).

8. *Dothidella Ulei* P. Hennings. „Sehr schädlich". Auf Blättern von jungen Heveapflanzen. Iquitos u. s. w. (P. Hennings).

9. *Aposphaeria Heveae* P. Henn. „Sehr schädlich". Auf Blättern gemeinschaftlich mit den beiden vorigen Arten (P. Hennings).

Wurzel-Krankheiten.

Die Kulturmethoden in den Dschungel-Ländereien erklären das Vorkommen der meisten tropischen Wurzelkrankheiten. Die großen Bäume werden gefällt, nicht ausgerodet, und um Arbeit zu sparen, werden sie gewöhnlich 2—3 Fuß hoch über dem Boden abgehauen oberhalb der Hauptwurzeln. Infolgedessen ist das gelichtete Land mit gewaltigen Baumstümpfen bedeckt, die zahllosen Polyporeen u. s. w. willkommene Nahrung darbieten. Die Vernichtung der Stümpfe bleibt gänzlich der Arbeit der Pilze überlassen. Man hat die Beobachtung gemacht, daß die Kulturpflanzen am häufigsten im zweiten oder dritten Jahre nach dem Pflanzen von Wurzelkrankheiten befallen werden, wenn nämlich die Pilze die Stümpfe zerstört und sich unterirdisch weiter verbreitet haben. Daraus ergibt sich, daß Wurzelkrankheiten kaum vorkommen, wenn die *Hevea* zwischen alten Teesträuchen angepflanzt wird, weil dann mit den Dschungelstümpfen schon seit Jahren aufgeräumt ist. Es gibt indessen auch spezifische Tee-Wurzelkrankheiten, die ihr Anfangsstadium auf den Stümpfen von *Grevillea robusta* u. s. w. durchmachen, wo diese als Schattenbäume angepflanzt und, als sie zu groß wurden, gefällt worden sind. Das Verlangen, daß diese Bäume ausgerodet werden sollten, wird als undurchführbar zurückgewiesen, hauptsächlich der Kosten wegen. So sehr dies vom Standpunkt des Mykologen zu beklagen ist, so muß doch zugegeben werden, daß die Maschinen, die in den gemäßigten Klimaten beim Ausroden oder zum Spritzen im Gebrauch sind, in den meisten Fällen für die Arbeit in den Tropen, oder wenigstens in Ceylon nicht geeignet sind. Die Ebene, solche Ländereien, wie sie in Europa vom Ackerbau in Anspruch genommen sind, werden hier seit undenklichen Zeiten für den Reisbau oder andere einheimische Produkte gebraucht, und der europäische Pflanzer muß sich mit steilen, felsigen, unregelmäßigen Hügeln begnügen, die der Landwirt gemäßigter Zonen dem Forstmann oder dem Touristen überlassen würde. Daher erregen die Bilder von Dampfspritzmaschinen oder von Dampfpflügen bei der Arbeit unter den Stümpfen, die zum Ankauf der

Maschinen verlocken sollen, nur ein mitleidiges Lächeln bei den Pflanzern.

Folgende Wurzelkrankheiten bei *Hevea brasiliensis* werden erwähnt:

10. *Fomes semitostus* Berk. Der Pilz entwickelt sich auf Dschungelstümpfen in neu angelegten Pflanzungen und geht auf *Hevea*, wenn die Pflanzen 2 bis 3 Jahre alt sind, mittelst weißer Mycelstränge über, die imstande sind, frei im Boden weiter zu wachsen. Er kommt besonders häufig auf den Stümpfen von *Artocarpus integrifolia* (= jak) vor. Auf der *Hevea* überzieht das Mycel die Hauptwurzel mit einem Geflecht weißer Stränge, von denen aus feine weiße Hyphen ins Innere der Wurzel dringen und sie weich und brüchig machen. Wenn der Baum abstirbt, ist über der Erde kaum etwas von dem Pilze zu sehen, und da die toten Stämme augenblicklich fortgeschafft werden, hat man in Ceylon niemals Fruchtkörper auf *Hevea* gefunden, obwohl sie im Laboratorium auf abgestorbenem Holze entwickelt werden konnten. In vielen Fällen wird die kranke Hauptwurzel von Termiten gänzlich zerstört, ehe der Baum abstirbt; der Baum wird dann durch die Seitenwurzeln ernährt, bis er vom Wind umgeworfen wird. In solchen Fällen werden häufig die Termiten allein für den Schaden verantwortlich gemacht; sie sind aber in Wahrheit Bundesgenossen des Pflanzers, weil sie durch ihre Arbeit die Weiterverbreitung des Mycels verhüten. (*Termes gestroi*, die in Malaya lebende Bäume anfallen soll, ist in Ceylon nicht bekannt.) In Ceylon ist kein Beispiel bekannt geworden, daß der Pilz ohne das Zwischenstadium auf den Dschungelstümpfen *Hevea* unmittelbar infiziert hätte, doch soll er auf alten *Hevea*-Bäumen, die durch Feuer gelitten hatten, im Botanischen Garten von Singapore vorgekommen sein. Das Ziehen von Gräben, Ausroden der Dschungelstümpfe und Bestreuen des Bodens mit ungelöschtem Kalk sind die besten Mittel, den Pilz zu bekämpfen.

Da Berkeley's Beschreibung sehr dürftig ist, so mögen folgende Notizen über den Pilz angebracht erscheinen: *Fomes semitostus* Berk. Ausdauernd, dachziegelig, holzig, Hut halbseitig, ungefähr 10 cm lang und 6 cm breit, wenn einfach durch seitliches Wachstum größer werdend; anfangs rotbraun mit verdicktem, gelbem Saum, später blaß gelbbraun mit konzentrischen, dunkelbraunen Ringen, weich, schwach gefurcht, ein wenig radial gestreift, seidig mit angedrückten Fibrillen. Dicke (durch zwei Poren Schichten) 1—1,5 cm. Rand dünn, ganz. Oberfläche der Poren orange, im Alter rotbraun, Poren klein, 0,6 –1,2 mm Durchmesser, ziemlich weit auseinander, im Durchschnitt rotbraun, 2,5—3,5 mm lang. Fleisch weiß, holzig, mit konzentrischen Wachstumslinien, die von dem Hymenium nach den oberflächlichen Furchen verlaufen.

11. *Poria vincta* Berk. und Broome. Einmal auf *Hevea brasiliensis* gefunden worden. Ceylon.

12. Wurzelbräune. Eine weit verbreitete Krankheit, aber glücklicherweise wächst der Pilz nur langsam und greift an einem Platze nicht weit um sich. Bringt *Hevea*, *Castilloa*, *Manihot*, Kakao, Tee, *Caravonica*-Baumwolle zum Absterben. Obwohl in den letzten 3 Jahren viele Beispiele bekannt und Versuche unternommen worden sind, um den Pilz auf kranken Wurzeln in Töpfen und Kulturkästen zu züchten, ist es nicht gelungen, Fruktifikationen aufzufinden. In einem Falle wanderte der Pilz eine Reihe von *Hevea*-Stämmen entlang, die 14 Fuß voneinander entfernt standen, alle zwei Jahre einen Baum abtötend; aber obgleich ich zur selben Zeit einen gerade absterbenden Baum, einen 2 Jahre alten Stumpf und die Überreste eines 4 Jahre alten Stumpfes beobachten konnte, habe ich nirgends Fruchtkörper gesehen. Der Pilz überzieht die Wurzel mit einem Filze von gelbbraunem Mycel, das allmählich ein schwarzes, fleckiges Aussehen annimmt. Die Wurzel ist innen morsch und von dünnen schwarzen Flecken oder Linien durchsetzt, wie sie von vielen Pyrenomyceten hervorgerufen werden. Aber das hervorstechendste Kennzeichen des Pilzes ist sein Vermögen, die Wurzel mit einer Menge Sand und kleiner Steinchen zu verkitten, wodurch ihr Umfang zuweilen verdoppelt wird. Bei direkter Berührung kann er von einer Wurzel auf die andere übergehen, auf andere Weise anscheinend nicht. Zweifellos ist er ein weitverbreiteter tropischer Wurzelpilz, und es existieren Berichte über eine ähnliche Krankheit beim Kakao aus anderen Ländern. Letztere scheint mit dem *Irpex flavus* identisch zu sein, der vor 20 Jahren eine Wurzelkrankheit beim Kaffee verursachte. Tee und Kakao werden häufig auf altem Kaffeeland angebaut. Berkeley hat Exemplare von *Irpex flavus* im Herbar von Peradeniya identifiziert, das sind aber nur Polster von gelbbraunen Hyphen, die nicht die geringste Ähnlichkeit mit *Irpex* haben und keine Spur von Fruchtkörpern besitzen. Ceylon.

13. *Sphaerostilbe repens* Berk. und Broome. Dieser Pilz ist 1875 nach Proben aus Ceylon von Berkeley und Broome beschrieben worden; er wurde auf *Artocarpus integrifolia* gefunden, es wird aber nichts über seinen Parasitismus erwähnt. Seitdem hat man ihn saprophytisch auf dem Holze von *Erythrina* gefunden und als Parasit in dem Rhizom von *Maranta arundinacea*. In letzterem Falle hat er zweifellos zuerst saprophytisch auf totem Holze vegetiert und ist mittelst seiner Rhizomorphen auf das Rhizom übergegangen. Neuerdings ist beobachtet worden, daß er *Hevea brasiliensis* zum Absterben brachte und zwar sowohl 30 Jahre alte, wie auch junge Bäume. Die Wurzeln sind von einem feinen, weißen Mycel durchzogen, das

Holz ist tief violett verfärbt und zwar in den kleinen Wurzeln ganz und gar, bei den größeren bis zwei Zoll tief. Das Hauptmerkmal des Pilzes ist jedoch die Entwicklung von Mycel zwischen Holz und Rinde. Das Mycel bildet zunächst rote, riemenartige Rhizomorphen, bis 1 cm breit und 2 mm dick; diese haben in der Regel eine zentrale und zahlreiche kurze, seitliche Furchen, gleich der Mittelrippe und den Adern eines Blattes. Von den Rhizomorphen gehen Seitenstränge ab und schließlich vereinigen sie sich alle zu einer zusammenhängenden Haut. Das Mycel stellt mithin eine fortlaufende Fläche dar mit einem voranschreitenden Saum von breiten Rhizomorphen, 5—6 cm lang. In dem Rhizom von *Arrowroot* sind die Rhizomorphen schmäler und vereinigen sich nicht. Das *Stilbum*-Stadium entwickelt sich in dichten Polstern am Wurzelhalse des Baumes und die Perithecien entstehen entweder auf dem durch Risse in der Rinde bloßgelegten Mycel oder auf den alten Conidienträgern. Diese Spezies hat im Mycel mit *Hypocreopsis* Ähnlichkeit und in der Anordnung der Perithecien häufig mit *Corallomyces*.

Die Conidienträger sind 2—8 mm hoch, 0,5—1 mm breit, zuerst rosa mit weißer Spitze und behaart, dann rötlich braun, an der Basis glatt, dicht unter dem runden weißen Kopfe behaart; Kopf 1—1,5 mm Durchmesser, Conidien breit oder schmal oval, an einem Ende zugespitzt oder beiderseits abgerundet $9 \times 6 — 2 \times 8$ μ groß. Die Perithecien sind dunkelrot, etwas rauh, etwa 6 mm hoch, von 4 mm Durchmesser, unten abgerundet, oben kegelförmig. Schläuche cylindrisch, gerade, $190—220 \times 9$ μ, Sporen einreihig. Sporen zweifächerig, oval, $9—21 \times 8$ μ, an der Scheidewand leicht eingeschnürt, blaßbraun oder rötlichbraun. Ceylon.

Stamm- und Zweigkrankheiten.

14. *Gloeosporium alborubrum* Petch. „Zurücksterben". Dieser Pilz greift hauptsächlich ein- bis zweijährige Schößlinge an, ist aber neuerdings auch auf älteren Bäumen gefunden worden. *Hevea* wächst in periodisch entstehenden Schossen, der jüngste Teil des Stammes besteht daher aus einem langen grünen Triebe mit einem Blätterbusch an der Basis und zerstreuten Blättern bis zur Spitze. Die infizierten Stellen dieses grünen Triebes werden dunkelbraun oder schwarz, sowohl an der Spitze wie in der Mitte des Triebes oder in dem Blätterbusch an der Basis. In einigen Fällen erkrankten die Blattstiele zuerst, fielen ab und infizierten den Stamm. Das kranke Gewebe wird zuerst weich, später hart und grau. Die Krankheit schreitet fort, bis der grüne Trieb abgestorben ist; bei Schößlingen greift sie rückwärts auf den alten holzigen Stamm bis zur Basis weiter; auf alten Bäumen macht sie bei den älteren Ästen Halt. Wenn die

kranken Spitzen junger Bäume abgeschnitten werden, macht der Baum neue Triebe und trägt nicht viel Schaden davon. Bei alten Bäumen werden die kranken Zweige abgeschnitten und verbrannt.

Die Perithecienform des Pilzes ist noch nicht gefunden worden. Infektionen mit den *Gloeosporium*-Sporen blieben ohne Erfolg. Ceylon.

15. *Phyllosticta ramicola* Petch. Auf grünen Stämmen gemeinsam mit dem vorigen. Ceylon.

16. *Corticium javanicum* Zimm. Ein in Java wohlbekannter Rindenparasit, kommt auch in Malaga und Südindien vor. In Ceylon ist er verhältnismäßig selten. obwohl er in den feuchteren Bezirken auf Tee, Cinchona und Pflaume gefunden worden ist. Er überzieht die Zweige mit einer dünnen. rosafarbigen Haut, tötet die kleineren ab und erzeugt auf den größeren offene Wunden. Die Fälle. die ich bei *Hevea* gesehen habe, kommen fast alle auf jungen Bäumen von etwa drei Zoll Durchmesser vor; die Rinde war rings um den Stamm mehrere Fuß lang abgestorben und hatte sich vom Holze gelöst, wodurch der Tod des Baumes herbeigeführt wurde. Diese rosa Haut zersplittert beim Älterwerden in unregelmäßige Stückchen. die einige Ähnlichkeit mit Hieroglyphen haben sollen. weshalb der Pilz auch „Schriftpilz“ genannt wird. Wahrscheinlich bezieht sich die Mitteilung betreffs des *Corticium calceum* auf *Hevea* in Malaya in Wirklichkeit auf *C. javanicum*. Man hat die Vermutung ausgesprochen, daß das *Corticium javanicum* die Ursache des *Hevea*-Krebses in Ceylon sei, aber das ist sicherlich nicht zutreffend. Ceylon, Java, Indien und Malaya.

17. *Pleurotus angustatus* Berk. u. Broome. Zuweilen, wenn alte *Hevea*-Bäume stark angezapft worden und die Schnitte bis aufs Holz gegangen sind, heilen die Wunden nicht aus, sondern es findet ein fortschreitendes Absterben statt. bis eine große Wundhöhle entsteht. Derartige Bäume werden gewöhnlich vom Winde abgebrochen. Es ist klar, daß die durch das Anzapfen zugefügte Verletzung die primäre Ursache des Absterbens ist. es muß aber hervorgehoben werden. daß in allen untersuchten Fällen sich *Pleurotus angustatus* auf den Wundstellen angesiedelt hatte. Das Mycel des Pilzes bildet zähe, rötliche Häute, die schnell durch den Stamm bis auf das gesunde Holz sich verbreiten. Er ist vermutlich imstande, als Wundparasit aufzutreten. Ceylon.

18. *Hexagonia polygramma* Mont. Diese Art ist verschiedene Male auf toten Zweigen von *Hevea brasiliensis* gefunden worden. Vielleicht ist der Pilz nur saprophytisch; indessen kommt er normal auf faulen Zweigen von *Mangifera indica*, *Bombax malabaricum* u. a., 20—50 Fuß hoch über dem Boden, vor. Diese Zweige brechen schließlich ab. Manche von ihnen sind ohne Zweifel von *Loranthus* abgetötet, aber

das ständige Vorkommen von *Hexagonia polygramma* dabei, sowie die Abwesenheit des Pilzes auf abgeschnittenen und vertrockneten Zweigen, sprechen doch für seinen Parasitismus. Ceylon.

19. *Megalonectria pseudotricha* Speg. In der Rinde von lebender *Hevea brasiliensis*, in einem Falle in Ceylon.

20. *Diaporthe Heveae* Petch. Auf toten Rindenstellen von *Hevea brasiliensis*. Ceylon.

21. *Phoma Heveae* Petch. In der Rinde, gemeinschaftlich mit den vorhergehenden Arten.

22. *Nectria coffeicola* Zimm. Mit *Corticium javanicum* zusammen auf toten Zweigen von *Hevea brasiliensis*, wahrscheinlich parasitisch. Java (Zimmermann).

23. *Stilbum Heveae* Zimm. Auf toten Zweigen von *Hevea brasiliensis*, wahrscheinlich nicht parasitär. Java (Zimmermann).

24. *Asterina tenuissima* Petch. Oberflächliche, sehr feine, schwarze Häute auf grünen Stämmen und Früchten von *Hevea brasiliensis* bildend. Ceylon. Unschädlich. Nach der Beschreibung von Parkin hat *Hevea* Nektarien an der Basis der Blattstiele. Auf den Sekreten dieser Nektarien entwickeln sich reichlich Schwärzepilze. Vielleicht wechselt die Art, die diese Flecke hervorruft, mit der Örtlichkeit.

25. *Marasmius rotalis* Berk. und Broome. „Pferdehaar Schimmel". Mit diesem Namen wird ein schwarzes, glänzendes Mycel von ungefähr 0,1 mm Durchmesser bezeichnet, das sich nach allen Richtungen über die Blätter und Zweige des Baumes ausbreitet, wie ein Gewirr von Pferdehaaren. Es kommt häufig in den Dschungeln und auch auf Tee und Muskatnuß vor, aber überall nur epiphytisch. Es ist auf zwischen Tee angepflanzter *Hevea* gefunden worden, auf die es von den Teesträuchern übergegangen war. Es ist nachgewiesen worden, daß dieses Mycel zu *Marasmius rotalis* gehört. Es werden noch verschiedene ähnliche Mycelien in den Dschungeln von Ceylon gefunden, von denen einige parasitisch sind.

26. *Botryodiplodia Elasticae* Petch. Befällt zuweilen kürzlich verpflanzte „stumps". Ist ein sehr verbreiteter Saprophyt auf abgestorbener *Hevea* und ausgesprochener Wundparasit auf *Castilloa elastica*. Greift wahrscheinlich die ruhenden „stumps" durch Wunden am Wurzelhalse, die beim Pflanzen entstanden sind, an. In einigen Fällen sind bis zu 60% der „stumps" zerstört worden. Der dadurch entstehende Schaden kann vermieden werden, wenn die Fehlstellen mit „Korbpflanzen" ausgefüllt werden.

27. Krebs Die Bezeichnung verschiedener Stammkrankheiten in Ceylon als „Krebs" hat bei den Mykologen anderer Länder irrige Anschauungen über die Natur dieser Krankheiten erweckt. Die Bildung einer offenen Wunde, wie sie z. B. bei dem Befall von *Nectria*

cinnabarina entsteht, kommt nur ganz ausnahmsweise bei den Krankheiten in Ceylon vor. Die Rinde wird innen verfärbt, meistens rot und stirbt in Platten ab; aber selbst wenn die ganze Rinde abgestorben ist, bleibt sie geschmeidig und fällt nicht herunter. In der Regel ist die kranke Rinde außerordentlich feucht; besonders auffallend ist das bei dem Kakaokrebs, wo der Stamm blutet, wenn die kranken Platten von Käfern angebohrt werden. Der Kakaokrebs schien zeitweilig die Kulturen in Ceylon mit dem Untergang zu bedrohen, wird aber jetzt durch regelmäßiges Ausschneiden der kranken Gewebe in Schranken gehalten. Es kann daher nicht Wunder nehmen, daß eine ähnliche Erscheinung bei *Hevea* 1903 die Pflanzer in die größte Besorgnis versetzte.

Äußerlich unterscheidet sich die krebsige *Hevea*-Rinde nur wenig von der normalen. In der Regel ist sie etwas dunkler. Innen hat sie eine schmutzig rote Farbe anstelle der weißen oder hellroten der gesunden Rinde. Obwohl auch etwas feucht, ist sie doch keineswegs so wasserreich wie die krebsige Kakaorinde, und blutet auch nicht. Wenn nichts dagegen geschieht, greift die Krankheit immer weiter um sich, bis die ganze Rinde in Mitleidenschaft gezogen ist, und der Baum stirbt ab. Wie beim Kakaokrebs kann die Krankheit durch Ausschneiden und Vernichten des kranken Gewebes zum Stillstand gebracht werden. Sie hat sich überhaupt als nicht so gefährlich gezeigt, wie es erst gefürchtet wurde; sie ist aber auch von Anfang an sorgfältig beobachtet und behandelt worden, so daß sie nirgends so festen Fuß fassen konnte wie der Kakaokrebs.

Der Kakao- und der *Hevea*-Krebs weisen manche Ähnlichkeiten auf; da aber von keinem von beiden die Ursache mit Bestimmtheit festgestellt worden ist, läßt sich bis jetzt nicht sagen, ob sie identisch sind. Beide sollen durch eine *Nectria* hervorgerufen werden, aber das Krankheitsbild ist ganz verschieden von dem *Nectria*-Krebs, und in beiden Fällen tritt die *Nectria* nur zusammen mit anderen saprophytischen Pilzen auf der toten Rinde auf. Beim Kakao ist es *Nectria striatospora*, die gemeinste *Nectria* auf totem Holz in Ceylon; bei *Hevea* ist es *Nectria diversispora* Petch, die auch auf abgestorbenen *Hevea*-Früchten vorkommt. Die Wahrscheinlichkeit spricht dafür, daß beide Krebse von Bakterien verursacht werden.

Krankheiten der Früchte.

28. *Phytophthora.* Die Frucht von *Hevea brasiliensis* reift während der stärksten Regenzeit. Sie ist daher sehr anfällig für eine *Phytophthora*-Fäule, die mit den Spezies auf Kakao- und Brotfrüchten identisch ist, obwohl die Fruchtkapsel holzig und nicht fleischig ist, wie bei letzteren. Die Frucht wird schwarz und bleibt am Baum hängen

oder fällt ab, ohne aufzuspringen. In der Regel kommt die Krankheit mit dem Eintritt guten Wetters zum Stillstand. Bis jetzt sind noch keine Maßregeln gegen die Krankheit getroffen worden, weil zur Zeit der Wert des *Hevea*-Samens nur gering und das Spritzen großer Bäume sehr kostspielig ist. Die Spezies konnte noch nicht bestimmt werden, weil es noch nicht gelungen ist, die Entwicklung von Zoosporen in den Sporangien zu verfolgen. Dieselbe Schwierigkeit liegt bei der Kakao-*Phytophthora* in anderen Ländern vor. Auf den faulenden Früchten werden *Nectria diversispora*, 29. *Diplodia zebrina* und 30. *Sphaeronema alba* gefunden.

Es mag bei dieser Gelegenheit darauf hingewiesen werden, daß die *Hevea*-Frucht bei der Reife aufplatzt und die Schalen mit den Samen zur Erde fallen. Ehe dies eingetreten, kann man eine Frucht nicht für reif ausgeben, daher wird das Verlangen nach „reifen Samen vom Baum gepflückt“ unweigerlich die Lieferung unreifer Samen veranlassen.

Präparierter Kautschuk.

31. *Eurotium candidum* Speg. In der feuchten Atmosphäre Ceylons wird der geronnene Kautschuk schimmelig, wenn er eine Zeit lang an der Luft liegen bleibt. Der Schimmel ist *Eurotium candidum* Speg. Eine Anzahl Proben von „wildem Kautschuk“ sind 1906 aus anderen Ländern zu der Kautschuk-Ausstellung nach Ceylon geschickt worden, und es stellte sich dabei heraus, daß in den meisten Fällen der natürlich geronnene Kautschuk, mit Rinde und Erde untermischt, garnicht, oder nur ganz wenig schimmelig wurde. Aber „harter Para“ wurde ganz ebenso schimmelig wie der Kautschuk aus den Plantagen Ceylons. In Ceylon wird der Kautschuk meistens durch Essigsäure zum Gerinnen gebracht und dann gewaschen; vielleicht begünstigt der dabei zurückbleibende kleine Säurerest das Wachstum der Schimmelpilze. Der Kautschuk leidet anscheinend nicht durch den Schimmel, der wahrscheinlich von den in dem Kautschukmassenblock zurückgebliebenen Proteinen zehrt.

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I. Kurze Übersicht über alle bisher auf Ficus elastica beobachteten Pilze, nebst Bemerkungen über die parasitisch auftretenden Arten.

Von

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Als ich im Jahre 1903 in Purworedjo (in der Provinz Kedu, in Mittel-Java in Niederländisch Ost-Indien) angestellt wurde und kurz nachher mit systematischen Untersuchungen über die Pilzflora von Ficus elastica Roxb. anfing, umfaßte dieselbe nur 16 Arten. Und nur vier Spezies waren damals auf Java nachgewiesen worden, nämlich Phomatospora Elasticae Zimm., Nectria Elasticae Zimm., Colletotrichum Elasticae Zimm. und Cercospora Elasticae Zimm., wo sie in West-Java von Prof. Dr. A. Zimmermann entdeckt und im Jahre 1901 in seiner Abhandlung über „Die tierischen und pflanzlichen Feinde der Kautschuk- und Guttapercha-Pflanzen" (in Bull. No. X de l'Inst. bot. de Buitenzorg(von ihm beschrieben waren. Die übrigen Arten waren nur von Gewächshauspflanzen, und zwar eine aus Amerika und zehn Arten aus Europa bekannt.

Durch meine obenerwähnte, bis zu meiner Abreise nach Europa im Juli 1906, in den sehr ausgedehnten, über 500 ha großen Anpflanzungen von Ficus elastica in Mittel-Java ausgeführten und im Juni 1907 im

Kgl. Botanischen Museum in Dahlem-Berlin von mir zum Abschluß gebrachten mykologischen Untersuchungen, ist die Artenzahl der genannten Pilzflora jetzt schon auf mehr als 50 gestiegen. Bisher hat, soweit bekannt, keine einzige Spezies erheblichen Schaden verursacht.

Die meisten sind entweder nur sehr schwache Wund-Parasiten oder nur Saprophyten. Die echten Parasiten hatten meist nur solche Ficus elastica-Pflanzen angegriffen, welche absichtlich (z. B. bei einigen Infektionsversuchen) oder zufällig (z. B. bei weitem Eisenbahntransport von Sämlingen, durch außergewöhnliche Trockenheit) in besonders ungünstige Kulturbedingungen geraten sind. Letzteres war z. B. mit dem fakultativ-parasitischen Colletotrichum Elasticae Tassi (= Zimm.) im Jahre 1904 in der Provinz Kedu der Fall.

Für eine mehr eingehend, durch Reinkulturen und wiederholt modifizierte Infektionsversuche von mir untersuchte, weit verbreitete Spezies konnte nachgewiesen werden, daß sogar Topfpflanzen, welche infolge des Angriffes des Pilzes die meisten Blätter verloren hatten, durch besonders sorgfältige Behandlung, und zwar durch besonders günstige Kulturbedingungen, wieder ganz gesunde Blätter erhielten und auch übrigens keine auffallende Krankheitserscheinungen mehr zeigten. Letzteres gelang z. B. mit einer Versuchspflanze in einem Gewächshaus des Kgl. Botan. Gartens in Dahlem-Berlin. Durch Impfung mit conidiogener Reinkultur von der fakultativ-parasitären, als Colletotrichum Ficus Kds. (siehe hier unten) beschriebene Conidienfruchtform von dem Ascomyceten Neozimmermannia elasticae (siehe auch unten) war es mir nämlich gelungen, auf den geimpften Blättern ausgedehnte abgestorbene Flecken mit zahllosen neuen Colletotrichum-Conidienlagern hervorzurufen, wodurch die Blätter vorzeitig abgeworfen wurden. Die vollständige Heilung der schwer erkrankten Pflanze gelang hier durch die gute Pflege des betreffenden Gewächshausgärtners, dem ich die kranke Pflanze mit spezieller Empfehlung nach Gelingen des Infektionsversuches übergeben hatte. Nach meinen sonstigen Beobachtungen gelingt aber eine solche Ausheilung durchaus nicht immer; selbst bei sorgfältigster Pflege.

Für diesen Pilz gelang es nachzuweisen, daß die höchste Fruchtform, nämlich die Ascusfruchtform, sich als Saprophyt, vorzugsweise auf den abgefallenen faulenden Blättern entwickelt resp. zur Reife kommt, während drei Nebenfruchtformen (nämlich eine interessante Chlamydosporenform und zwei früher als selbständige Fungi imperfecti beschriebene Conidien-Fruchtformen: Gloeosporium Elasticae Cooke & Massee und Colletotrichum Ficus Kds.) sich nicht nur in künstlichen Nährlösungen als Saprophyten, sondern auch als echte Blatt- und Stengelparasiten üppig entwickeln können.

Dieser letzte Fall wird von mir erwähnt, weil daraus hervorgeht, daß auch die Kenntnis der auf faulen Blättern von Ficus elastica lebenden Pilze nicht nur in wissenschaftlicher, sondern auch in praktischer Hinsicht nützlich sein kann, wie solches von anderen, (z. B. durch Went, Klebahn u. a.) für andere Pilze nachgewiesen ist.

Die in den Wurzeln von Ficus elastica lebenden Pilze habe ich, aus Mangel an Zeit, nicht in den Kreis meiner Untersuchung aufgenommen. Hauptsächlich habe ich die auf Blättern und Zweigen gefundenen Pilze untersucht. Über Wurzeln bewohnende Pilze liegen für Ficus elastica in der Literatur noch keine Beobachtungen vor.

Wenn wir die jetzt schon über 50 Arten starke Pilzflora übersehen, ist vor allem bemerkenswert, daß die auch in Java wichtige Krankheiten bei Kulturpflanzen hervorrufenden Familien der Rostpilze und Brandpilze (Uredineae und Ustilagineae) noch nie auf Ficus elastica gefunden worden sind. Ferner ist noch folgendes bemerkenswert: Die Pilzflora der oberirdischen Teile von Ficus elastica besteht fast ganz aus Fungi imperfecti (70 %) und Ascomyceten (30 %), die Basidiomyceten sind nur durch zwei Arten vertreten, und die Phycomyceten, sowie Myxomyceten sind noch nicht auf Ficus elastica gesammelt worden. Unter den Ascomyceten gehören fast alle zu den Pyrenomycetineae und von diesen fast alle zu den Sphaeriales.

Die Fungi imperfecti überwiegen nicht nur durch Artenzahl, sondern auch durch Individuen-Anzahl und durch großen Formenreichtum. Die am meisten vorkommenden Arten sind durch dunkelgefärbte Mycelwände und widerstandsfähige, braunwandige Conidien charakterisiert. Unter den Sphaeropsidales ist eine meist nur saprophytisch lebende, aber selten parasitär auftretende Diplodia außerordentlich allgemein. Unter den Melanconiales sind die Gattungen Gloeosporium, Septogloeum und Pestalozzia mit je einer Art und ferner durch zwei Spezies von der Gattung Colletotrichum vertreten. Die erstgenannte Art und eine der beiden letztgenannten „Spezies“ sind nur Nebenfruchtformen von einem und demselben Ascomyceten, wie oben schon gesagt wurde. Unter den im Freien auf Blättern, z. T. zuweilen auch als Wundparasit vorkommenden Hyphomyceten sind die Dematiaceae durch acht Gattungen bemerkenswert. Unter den Tuberculariaceae verdient hier Necator als bisher für Ficus elastica seltener, aber ausgeprägt obligater Parasit Erwähnung, und die Gattung Wiesneriomyces verdient hier hervorgehoben zu werden, wegen des interessanten und zierlichen Baues der Conidienlager, sowie darum, weil Conidienaussaat in Hängetropfenkultur Anlagen von Ascosporenfrüchten ergeben hat. Leider waren die von mir (in Mittel-Java) erzielten Schlauchfruchtanlagen, als ich durch meine Abreise den Versuch ab-

brechen mußte, noch nicht ganz reif. Diese Beobachtung bleibt aber interessant, weil bekanntlich derartige Fälle (der Ascusfruchtbildung in Nährlösung durch Conidienaussaat) äußerst selten sind.

Die in dieser Übersicht erwähnten neuen Gattungen (Neohenningsia, Wentiomyces, Neozimmermannia, Lindauomyces, Acrotheciella und Wiesneriomyces) sowie alle neue Arten sind von mir beschrieben und zum größten Teil auch abgebildet in dem vierten Abschnitt einer sich jetzt im Druck befindlichen Abhandlung: „Botanische Untersuchungen über einige in Java vorkommende Pilze, besonders über Blätter bewohnende parasitisch auftretende Arten in Verhandelingen der Koninklyke Akademie van Wetenschappen in Amsterdam, Band XIII (1907)“.

Wie in der soeben zitierten Abhandlung, so habe ich auch hier Herrn Geh. Ober-Regierungsrat Prof. Dr. A. Engler, Direktor des Kgl. Botanischen Gartens und Museums in Dahlem-Berlin, für die mir gütigst zur Verfügung gestellten Arbeitsräume und wissenschaftlichen Hilfsmittel meinen Dank auszusprechen; auch den Herrn Kustoden Professor P. Hennings und Prof. Dr. G. Lindau bin ich zu aufrichtigem Danke verbunden für das liebenswürdige Interesse, welches sie meiner Arbeit zuwandten. Ohne ihre selbstlose Hilfsbereitschaft hätte ich wohl oft vergeblich unter der Saccardoschen Diagnosen mich zurechtzufinden gesucht.

Die Anordnung der Familien ist dieselbe, wie sie in Englers Syllabus (5. Auflage) angenommen ist.

§ I. ASCOMYCETES.

I. Pezizineae.

Pezizaceae.

1. **Pezizella Elasticae** Kds. l. c. Ascusfruchtform saprophytisch auf Blättern, besonders auf dem Blattstiel; in Mittel-Java von mir beobachtet.

Patellariaceae.

2. **Karschia Elasticae** Kds. l. c. Ascusfruchtform saprophytisch oder vielleicht auch als sehr schwacher Parasit auf der Stammrinde junger angepflanzter Bäume, in der Nähe früherer Schnittwunden; in Mittel-Java von mir gefunden.

II. Phacidiineae.

Tryblidiaceae.

3. **Tryblidium Elasticae** Kds. l. c. Ascusfruchtform in Mittel-Java auf der Stammrinde junger angepflanzter Bäume, in der Nähe alter

Schnittwunden, von mir beobachtet; saprophytisch oder vielleicht auch schwach parasitisch.

III. Hysteriineae.

Hysteriaceae.

4. Hysterographium Elasticae Kds. l. c. Ascusfruchtform in Mittel-Java auf der Stammrinde junger angepflanzter Bäume, in der Nähe von alten (durch Ernten des Kautschuks entstandenen) Schnittwunden von mir beobachtet; nur als schwacher Parasit oder meist als Saprophyt.

IV. Plectascineae.

Aspergillaceae.

5. Neohenningsia stellatula Kds. l. c. Ascusfruchtform saprophytisch auf Blättern in Mittel-Java von mir gefunden. Die neue Gattung Neohenningsia Kds. l. c. wurde von mir benannt nach Prof. Dr. P. Hennings in Berlin.

V. Perisporiineae.

1. *Perisporiales.*

Perisporiaceae.

6. Wentiomyces javanicus Kds. l. c. Ascusfruchtform saprophytisch auf Blättern von Ficus elastica in Mittel-Java von mir gefunden. Die neue Gattung Wentiomyces Kds. l. c. wurde von mir benannt nach Prof. Dr. F. A. F. C. Went in Utrecht.

Microthyriaceae.

7. Asterula Bruinsmai Kds. l. c. Ascusfruchtform saprophytisch auf Blättern in Mittel-Java von mir beobachtet.

2. *Hypocreales.*

Hypocreaceae-Melanosporeae.

8. Melanospora Wentii Kds. l. c. Ascusfruchtform und Chlamydosporen saprophytisch auf Blättern in Mittel-Java von mir beobachtet.

Hypocreaceae-Nectrieae.

9. Nectria (Dialonectria) gigantospora Zimmerm. Ascusfruchtform im Buitenzorger Kulturgarten auf Blättern, und häufig auf jungen Blättern, vereinzelt und nur auf stark beschatteten Blättern von Prof. Dr. A. Zimmermann entdeckt. Nach Zimmermann ist es zweifelhaft, ob der Pilz wohl jemals für die Kultur im großen schädlich werden wird. Von mir ist der Pilz auch nie als schädlich für große Kulturen, und zwar nur als Saprophyt, in Mittel-Java beobachtet.

10. Nectria (Lasionectria) Elasticae Kds. l. c. Ascusfruchtform saprophytisch auf Blättern in Mittel-Java von mir beobachtet.

11. Megalonectria pseudotrichia Speg. Ascusfruchtform bisher auf Ficus elastica noch nicht gefunden, dagegen die als Stilbella cinnabarina (Mont.) Lindau von den verschiedensten Nährpflanzen, auch von Java, bekannte Conidienfruchtform saprophytisch auf F. elast. von mir in Mittel-Java beobachtet und zwar auf der Rinde abgestorbener alter Zweige.

3. *Dothideaceales.*

Dothideaceae.

12. Hyalodothis incrustans Raciborski. Dieser Pilz ist bisher von mir und wie es scheint, auch von anderen noch nie auf F. elast. gefunden. Weil aber Zimmermann (l. c. p. 16) diese Art aufgenommen hat in seiner Publikation über „Die tierischen und pflanzlichen Feinde der Kautschuk- und Guttaperchapflanzen (in Bull. bot. Buitenz. No. X, 1901)", und zwar nur mit folgenden Worten: Hyalodothis incrustans Rac., wurde von Raciborski (Parasitische Algen und Pilze Javas, III [1900] p. 12) in Buitenzorg auf der Oberseite großer Ficusblätter beobachtet, ohne zugleich hervorzuheben, daß der Pilz von Raciborski l. c. nur für eine nicht mit Speziesnamen umschriebene Ficus-Art erwähnt wurde, sei hervorgehoben, daß dieser parasitische Blattpilz von mir, und wie es scheint, auch von anderen noch nie auf Ficus elastica gefunden wurde.

4. *Sphaeriales.*

I. Chaetomiaceae.

13. Chaetomium Elasticae Kds. l. c. Ascusfrüchte von mir beobachtet als Saprophyt auf Blättern von F. elast., welche aus Java nach Deutschland mitgebracht worden waren und dort im Kgl. Bot. Garten in Dahlem-Berlin im Thermostat aufgehoben worden waren.

II. Sphaeriaceae.

14. Coleroa Elasticae Kds. l. c. Ascusfruchtform meist als echter Parasit, aber auch als Wundparasit, auf erwachsenen und besonders auf sehr alten (fast hinfälligen) Blättern, seltener auch auf der grünen Rinde junger Zweige und Stämmchen von F. elast. in Mittel-Java in der Provinz Kedu, und dort auf den oberirdischen Teilen derselben Nährpflanze, auch als Saprophyt, von mir beobachtet. Ich fand die Ascusfrüchte auch auf lebenden Blättern von F. elast., welche mir durch Herrn Kgl. Oberförster Th. Salverda in Bandong (Java) zur Untersuchung gütigst zugeschickt wurden und von Herrn Adjunct-Ober-

förster Haag in den Kautschukkulturen von Krawang (in West-Java) gesammelt worden waren.

III. Mycosphaerellaceae.

15. Mycosphaerella Elasticae Kds. l. c. Ascusfruchtform parasitisch auf erwachsenen Blättern von F. elast. nur sehr vereinzelt in Mittel-Java von mir beobachtet.

16. Neozimmermannia Elasticae Kds. l. c. Die Ascusfruchtform wurde von mir beobachtet auf faulenden Blättern und in der Rinde faulender junger Zweige und Stämmchen von jungen Pflanzen, sowohl auf Java (bei den im Freien stehenden Pflanzen) wie auch in Deutschland, aber hier nur auf Gewächshauspflanzen des Kgl. Bot. Gartens in Dahlem-Berlin, und zwar auf Stecklingen, welche aus Niederl. Ost-Indien importiert worden sind. — Die neue Gattung Neozimmermannia Kds. l. c. ist von mir benannt nach Prof. Dr. A. Zimmermann in Amani in Deutsch-Ostafrika.

IV. Pleosporaceae.

17. Physalospora Elasticae Kds. Ascusfruchtform als Wundparasit und nur sehr vereinzelt in Mittel-Java auf erwachsenen von F. elast. von mir beobachtet worden.

18. Metasphaeria tetrasperma Kds. l. c. Ascusfruchtform als Saprophyt und sehr schwacher Wundparasit auf der Stammrinde junger angepflanzter Bäume von F. elast. in Mittel-Java von mir beobachtet worden und nur sehr vereinzelt.

V. Gnomoniaceae.

19. Phomatospora Elasticae Zimmermann, höchst wahrscheinlich identisch mit Neozimmermannia Elasticae Kds. Schon Zimmermann, der die Ascusfrüchte auf faulenden Blättern von F. elast. entdeckt und dieselben zuerst beschrieben hat (l. c. p. 15), erwähnte, wie aus der Bemerkung unter seiner Diagnose hervorgeht, daß dieselbe nicht gut in die Gattung hineinpaßte, in welche er den Pilz, unter dem obenerwähnten Namen, hineingestellt hatte. Durch eine detaillierte Untersuchung habe ich feststellen können, daß die von mir in Mittel-Java auf derselben Nährpflanze entdeckten und durch Reinkulturen und Infektionsversuche als zugehörig zu Colletotrichum Ficus Kds. erwiesenen Ascusfrüchte höchst wahrscheinlich identisch sind mit Phomatospora Elasticae Zimm. und ferner, daß der Bau der Ascusfruchtform nicht nur in den von Zimmermann ganz richtig hervorgehobenen Charakteren von der Gattung Phomatospora Sacc. abweicht, sondern, daß dieselbe auch in anderen Hinsichten so bemerkenswerte Unter-

schiede zeigt, daß der Pilz als Typus einer neuen Gattung gilt, die ich zu Ehren von Prof. Dr. A. Zimmermann als Neozimmermannia beschrieben habe (vgl. oben in der Einleitung).

VI. Clypeosphaeriaceae.

20. Linospora Elasticae Kds. l. c. Ascusfruchtform saprophytisch auf Blättern von F. elast. in Mittel-Java sehr häufig von mir beobachtet.

21. Anthostomella Elasticae Kds. l. c. Ascusfruchtform als Saprophyt oder als schwacher Wundparasit auf Blättern von F. elast. in Mittel-Java nur sehr vereinzelt von mir beobachtet.

§ 2. BASIDIOMYCETES.

PROTOBASIDIOMYCETES.

1. Auriculariineae.

22. Auricularia Auricula-Judae (Linn.) Schröter. In Mittel-Java wurde dieser kosmopolitische Pilz saprophytisch auf Rinde und Holz von F. elast. (wie auch auf zahlreichen anderen Nährpflanzen) von mir beobachtet.

AUTOBASIDIOMYCETES.

2. Hymenomycetineae.

Eine noch nicht fruktifizierende und dadurch nicht ganz bestimmbare **Cyphella** wurde auf Blättern von F. elast. aus Mittel-Java beobachtet als Saprophyt.

§ 3. FUNGI IMPERFECTI.

I. Sphaeropsidales.

Sphaerioideaceae.

23. Phyllosticta Elasticae Kds. l. c. In Mittel-Java auf Blättern von F. elast. als Saprophyt und mit Zweifel auch als Wundparasit sehr häufig von mir beobachtet.

24. Phyllosticta Roberti Boy. et Jacz., bisher nur aus Süd-Frankreich bekannt. Dieser Pilz wurde nach Saccardo (Syll. Fung. XI, 476) in Frankreich bei Montpellier in einem Gewächshaus auf Blättern von F. elast. gefunden. Zimmermann l. c. p. 16 erwähnt den Pilz nur auf Autorität von Saccardo und scheint ihn auf Java nicht gefunden zu haben. Ich fand wohl eine Art von Phyllosticta auf Java auf der genannten Nährpflanze, aber dieselbe war spezifisch nicht damit identisch (siehe oben).

25. Phoma Zehntneri Kds. l. c. In Mittel-Java als Parasit in Stamm- und Astrinde von jungen angepflanzten Bäumen von F. elast.

Hier spielte der Pilz zugleich mit Fusicoccum Elasticae Kds. und Diplodia Wurthii Kds. eine Rolle bei einer Einschnürungskrankheit der genannten Nährpflanze. Auch vereinzelt als Parasit und Saprophyt in einem Gewächshaus des Kgl. Botan. Gartens in Dahlem-Berlin von mir beobachtet, aber hier nicht in Gesellschaft der beiden genannten Sphaeropsidales und hier keine Einschnürungskrankheit hervorrufend.

26. Phoma atro-cincta Saccardo, bisher nur von Italien bekannt. Diese Art ist bisher nur in Italien, in einem Gewächshaus in Rom, auf abgestorbenen Blättern von F. elast. von Saccardo beobachtet.

27. Harknessia. „Als Harknessia? bezeichnet Van Breda De Haan (Bull. de l' Institut bot. de Buitenzorg No. 6, 1900, p. 12) einen Pilz, der von ihm auf totem Wurzelholz von Ficus elastica beobachtet wurde." (Zimmermann Bull. l. c. p. 16.) — In Mittel-Java wurde noch keine Harknessia auf F. elast. beobachtet.

28. Fusicoccum Elasticae Kds. l. c. In Mittel-Java in Zweigrinde von angepflanzten jungen Bäumen von F. elast. als Parasit und als Saprophyt von mir beobachtet und zwar in einem Falle in Gesellschaft von Phoma Zehntnerii Kds. und Diplodia Wurthii Kds. an einem Zweig, welcher Einschnürungskrankheit zeigte.

29. Diplodia Wurthii Kds. In Mittel-Java als Wundparasit und als Saprophyt auf Blättern und in der Rinde von Zweigen und vom Stamme junger Bäume von F. elast. von mir sehr häufig beobachtet; aber trotz der Häufigkeit dieses Pilzes in Mittel-Java habe ich ihn nie auf Gewächshauspflanzen in Europa gefunden. Die Art wurde auf F. elast. auf Java zuerst beobachtet von Dr. Th. Wurth, Botaniker der Allgemeinen Versuchsstation in Salatiga (Java), jedoch von dem Entdecker noch nicht beschrieben.

30. Septoria Elasticae Kds. l. c. In Mittel-Java auf Blättern von F. elast. als Saprophyt von mir beobachtet.

31. Septoria brachyspora Sacc. wurde von Saccardo (Syll. Fung. III, p. 500) in Frankreich auf Blättern von Ficus elastica nachgewiesen, aber wurde bisher nicht auf Java gefunden.

II. Leptostromataceae.

32. Leptostromella elastica Ell. u. Ev. wurde nach Saccardo (Syll. Fung. X, p. 430) in Nordamerika auf Blättern von Ficus elastica beobachtet, ist aber bisher in Java noch nicht beobachtet worden.

III. Melanconiales.

Melanconiaceae.

33. Gloeosporium intermedium Sacc. var. **brevipes** Saccardo (Syll. Fung. III, p. 703) ist als Konidien-Fruchtform von Neo-

zimmermannia Elasticae Kds. von mir nachgewiesen worden (siehe oben).

34. Gloeosporium Elasticae Cooke & Massee. Diesen von Cooke & Massee als selbständige Spezies beschriebenen Pilz habe ich schon früher auf Grund des mir durch Dr. D. Prain, Direktor des Kgl. Botan. Gartens von Kew und Herrn G. Massee, Cryptogamic botanist an genanntem Garten, zur Untersuchung überlassenen authentischen Materiales identisch erklären können mit Colletotrichum Ficus Kds. und folglich nur als Konidien-Fruchtform von dem Pyrenomyceten Neozimmermannia Elasticae Kds. (siehe oben und auch im Notizblatt des Kgl. Botan. Gartens und Museums in Dahlem-Berlin Nr. 38 [1906] p. 251).

35. Colletotrichum Ficus Kds. l. c. Durch Reinkulturen und Infektionsversuche habe ich feststellen können, daß dieser früher als selbständige Spezies beschriebene Pilz im Entwicklungskreise von dem Ascomyceten Neozimmermannia Elasticae Kds. mit Gloeosporium Elasticae Cooke & Massee hineingehört, und zwar als eine borstentragende, vorwiegend als Blatt-Parasit oder als Rinden-Parasit von jungen Zweigen und sehr jungen Stämmchen lebende Konidien-Fruchtform.

36. Colletotrichum Elasticae Tassi. Von Tassi in Italien in einem Gewächshaus auf abgestorbenen Blättern entdeckt und beschrieben. Durch das mir von Professor Dr. Flam. Tassi gütigst zur Untersuchung zugeschickte authentische Herbarmaterial konnte ich die Identität von der auf Java vorkommenden Colletotrichum Elasticae Zimmermann mit C. Elasticae Tassi feststellen. Weil Tassi die Art früher als Zimmermann publizierte, muß die Art künftig als C. Elasticae Tassi bezeichnet werden.

Diese unter anderen durch die immer sichelförmigen spitzen Konidien und die außergewöhnlich langen Borsten scharf von Colletotrichum Ficus Kds. unterschiedene Species bildete, obwohl ich dieselbe mehr als zwei Jahre kultivierte und während dieser Zeit wiederholt Infektionsversuche damit ausführte (in scharfem Gegensatze zu meinen Versuchen mit Colletotrichum Ficus Kds.), keine Ascosporen-Fruchtform. Es wurden nur noch Chlamydosporen als zweite Nebenfruchtform von C. Elasticae Tassi erhalten. C. Elasticae Tassi fand ich in Mittel-Java auf F. elast. meist nur als Saprophyt und ausnahmsweise als Parasit auf Blättern. Die Art ist durch Zimmermann auch von West-Java als Blattparasit bekannt geworden.

Infektionsversuche mit jungen Topfpflanzen (mit konidiogenen Reinkulturen) brachten nur dann eine auffallende Erkrankung mit Bildung von neuen Konidienlagern auf den Blättern hervor, wenn für Entwicklung des Pilzes möglichst günstige und für die Versuchspflanzen möglichst

ungünstige Bedingungen gewählt wurden. Durch Versuche konnte ich feststellen, daß die Chlamydosporen bei der Infektion eine wichtige Rolle spielen.

Infektionsversuche, welche ich bei F. elast. anstellte mit Reinkulturmaterial, das abstammte von einem mir von Dr. Th. Wurth aus Salatiga (Java) zugesandten, auf Coffea arabica von ihm entdeckten (von C. incarnatum Zimm. scharf verschiedenen) und von ihm für C. Elasticae Zimm. bestimmten Spezies, ergaben Resultate, welche in gewissen Beziehungen Abweichungen zeigten von Infektionsresultaten, welche ich bei F. elast. erzielte mit Reinkulturmaterial, das ursprünglich von Konidienlagern von dem unzweifelhaften Colletotrichum Elasticae Tassi (= Zimm.) von F. elast. stammte. Hier ist kein Platz, hierauf näher einzugehen.

37. Colletotrichum Elasticae Zimm. ist, wie erwähnt, von mir als identisch mit dem soeben behandelten Colletotrichum Elasticae Tassi und spezifisch scharf verschieden von Colletotrichum Ficus Kds. nachgewiesen.

38. Septogloeum Elasticae Kds. l. c. In Mittel-Java als echter Blattparasit von Ficus elast. von mir beobachtet, aber nur höchst selten und bisher nur bei einigen Topfpflanzen, welche für Infektionsversuche benutzt worden waren. In den über 500 Hektar großen Anpflanzungen von Ficus elastica in der Provinz Kedu (Mittel-Java) noch nicht beobachtet und auch noch nicht aus anderen Gegenden bekannt.

39. Pestalozzia Elasticae Kds. l. c. In Mittel-Java als Wundparasit auf Blättern von F. elast. nur sehr vereinzelt auftretend und bisher keinen Schaden verursachend. — Mit Rücksicht auf den letzten Punkt sei hier hervorgehoben, daß für Java zwei andere Pestalozzia-Arten, nämlich P. palmarum Cooke und P. Myricae Kds. unter Umständen großen Schaden verursachen können. Für P. palmarum ist dieses von Dr. Bernard (Teysmannia XVIII, 1907, p. 327, wo auch übrige Literatur angegeben ist) besonders bei Cocos nucifera L. und von mir für P. Myricae bei Myrica javanica Bl. nachgewiesen.

IV. Hyphomycetes.

Dematiaceae.

40. Acrostalagmus cinnabarinus Corda, bisher nur im Kgl. Bot. Garten in Dahlem-Berlin und als Saprophyt auf Blättern von F. elast. in einem Gewächshaus.

41. Stachybotrys Elasticae Kds. l. c. In Mittel-Java saprophytisch auf Blättern von F. elast. von mir beobachtet.

42. Periconia javanica Kds. l. c. In Mittel-Java auf Blättern von F. elast. und zwar nur von sehr jungen Saatpflanzen als Parasit und Saprophyt und nur sehr vereinzelt von mir beobachtet.

43. **Periconia Elasticae** Kds. l. c. In Mittel-Java als Saprophyt und ausnahmsweise auch als Wundparasit auf Blättern und auf der Stammrinde sehr junger Saatpflanzen von mir beobachtet.

44. **Catenularia Elasticae** Kds. l. c. Als Saprophyt auf Blättern von F. elast. in einem Thermostat des Kgl. Botan. Gartens in Dahlem-Berlin von mir beobachtet. — Nur in Gesellschaft von der Ascosporen-Fruchtform von Chaetomium Elasticae Kds., wovon diese Catenularia vielleicht die Konidien-Fruchtform sein könnte.

45. **Fusicladium Elasticae** Kds. l. c. In Mittel-Java auf Blättern von F. elast. sehr vereinzelt als Wundparasit oder als Saprophyt von mir beobachtet.

46. **Clasterosporium Elasticae** Kds. l. c. In Mittel-Java auf Blättern von F. elast. als Saprophyt oder sehr vereinzelt auftretender Wundparasit von mir beobachtet.

47. **Clasterosporium javanicum** Kds. l. c. Als Wundparasit auf Blättern von F. elast. in Mittel-Java nur ein einziges Mal von mir beobachtet.

48. **Helminthosporium Elasticae** Kds. l. c. In Mittel-Java auf Blättern von F. elast. saprophytisch und sehr vereinzelt, auch als Wundparasit auftretend, von mir beobachtet.

49. **Napicladium Elasticae** Kds. l. c. In Mittel-Java auf Blättern von F. elast. sehr vereinzelt als Wundparasit oder als Saprophyt von mir beobachtet.

50. **Cercospora Elasticae** Zimmermann. Auf Blattflecken von F. elast. in West-Java von Zimmermann entdeckt und später in Mittel-Java (nur selten) von mir gefunden. Der Pilz wurde von mir in Mittel-Java nur auf jungen Topfpflanzen und nur als schwacher Parasit beobachtet.

Stilbaceae.

51. **Stilbella Elasticae** Kds. l. c. In Mittel-Java nur ein einziges Mal auf dem Stämmchen einer nur wenige Monate alten Saatpflanze von F. elast. als Parasit von mir gefunden.

52. **Actiniceps Thwaitesii** Berk. et Br. In Mittel-Java auf Blättern von F. elast. sehr allgemein als Saprophyt, aber nie parasitisch, von mir beobachtet. — Dieser außergewöhnlich zierlich gebaute, mit dem bloßen Auge kaum sichtbare Pilz wurde von Prof. Dr. Penzig in West-Java, auch als Saprophyt, auf anderem Substrate nachgewiesen.

53. **Coremium Elasticae** Kds. l. c. In Mittel-Java auf Blättern von F. elast. saprophytisch von mir beobachtet.

54. **Lindauomyces javanicus** Kds. l. c. In Mittel-Java auf Blättern von F. elast. sehr selten und nur als Wundparasit von mir

beobachtet. — Die neue Gattung Lindauomyces Kds. l. c. wurde von mir benannt nach Prof. Dr. G. Lindau in Berlin.

Tuberculariaceae.

55. Hymenula Elasticae Kds. l. c. In Mittel-Java auf Blättern von F. elast. als Saprophyt und als wenig schädlicher Wundparasit von mir beobachtet.

56. Dacrymycella Beijerinckii Kds. l. c. In Mittel-Java als Wundparasit einer sehr jungen Saatpflanze von F. elast. von mir beobachtet und zwar in der Rinde und auf dem durch Verletzung entblößten Holze des Stämmchens.

57. Necator decretus Massee. In Mittel-Java als echter Parasit auf der Rinde des Stämmchens einer sehr jungen Saatpflanze von F. elast. von mir beobachtet.

Dieser bekanntlich für einige tropische Kulturpflanzen (z. B. für Kaffee usw.) zuweilen sehr schädliche Parasit wurde in den über 500 Hektar großen Anpflanzungen von F. elast. in der Provinz Kedu nur ein einziges Mal von mir als Parasit von F. elast. konstatiert. In diesem erwähnten Fall jedoch als vermutliche Ursache des Absterbens einer sehr jungen, erst kurz vorher ausgepflanzten Saatpflanze.

58. Chaetospermum Elasticae Kds. l. c. In Mittel-Java auf Blättern von F. elast. ziemlich häufig, aber nur als Saprophyt von mir beobachtet.

59. Volutella Elasticae Kds. l. c. In Mittel-Java auf Blättern von F. elast. saprophytisch von mir beobachtet.

60. Wiesneriomyces javanicus Kds. l. c. In Mittel-Java auf Blättern von F. elast. saprophytisch von mir beobachtet, aber bisher nur an einem einzigen Fundort, nämlich bei dem Dorf Penunggalan in der Provinz Kedu; dort aber nicht selten. (Siehe auch oben in der Einleitung.)

Die neue Gattung Wiesneriomyces Kds. l. c. wurde von mir benannt nach Hofrat Prof. Dr. J. Wiesner in Wien.

61. Fusarium javanicum Kds. l. c. In Mittel-Java auf Blättern von F. elast. saprophytisch von mir beobachtet.

62. Fusarium Urticearum (Corda) Saccardo. In Italien und Böhmen saprophytisch auf Zweigen von F. elast. von Saccardo (Syll. Fung. IV, p. 4698) beobachtet, aber bisher noch nicht auf Java gefunden.

63. Hymenopsis Elasticae Kds. l. c. In Mittel-Java auf Blättern von F. elast. saprophytisch von mir beobachtet.

64. Acrotheciella javanica Kds. l. c. In Mittel-Java auf Blättern von F. elast. als wenig schädlicher Wundparasit von mir beobachtet.

V. Mycelia sterilia.

65. Sclerotium. Prof. Dr. A. Zimmermann entdeckte in West-Java auf Blättern von F. elast. ein Sclerotium, wovon die Keimung nicht gelang. In Mittel-Java wurde dieses Sclerotium noch nicht beobachtet.

Kgl. Bot. Museum in Dahlem-Berlin, Juli 1907.

Dr. S. H. Koorders.

On Lasiodiplodia.

BY

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THE genus *Diplodia* forms a huge unwieldy group of weakly differentiated species, and any method of subdividing it into smaller groups would be welcomed. But it is evident that some of the present subdivisions, though they may appear distinct on paper, only lead to confusion in practical mycology.

Saccardo, in "Sylloge Fungorum," Vol. III., adopts the following scheme of subdivision :—

§ Pycnidia discreta.

† Pycnidia tecta vel erumpentia.

Diplodia.—Pycnidia glabra ; sporulæ strato mucoso carentes.

Macrodiplodia.—Pycnidia glabra ; sporulæ strato mucoso obvolutæ.

Chætodiplodia.—Pycnidia pilosa ; sporulæ strato mucoso carentes.

†† Pycnidia lignicola, subsuperficialia.

Diplodiella.—Pycnidia subcarbonacea, papillata.

§§ Pycnidia cæspitosa.

Botryodiplodia.—Pycnidia cæspitoso-erumpentia.

Except that *Chætodiplodia* may be "*setosa vel pilosa*," no further differences are disclosed by the subgeneric descriptions.

In the "Botanical Gazette," Vol. XXI., No. 2, p. 92 (February, 1896), another subgenus, *Lasiodiplodia*, was described by Miss Ida Clendenin. The fungus for which this subgenus was instituted, *Lasiodiplodia tubericola*, was found on sweet potatoes which had been imported from Java, and was submitted to Ellis, who decided that it was worthy of separate generic rank. Hence *Lasiodiplodia* is attributed, in the article referred to, to Ellis and Everhart. The generic characters

are—"Perithecia collected in a stroma, clothed with brown mycelium; basidia and sporules with paraphyses intermingled; otherwise as in *Diplodia*."

Since then other subgenera have been instituted, viz. :—*Microdiplodia*, with distinct pycnidia, and spores less than 15 μ long; *Pellionella*, with subsuperficial pycnidia produced into a beak, "*Est Diplodiella rostrata*"; *Rhynchodiplodia*, which is a beaked *Chætodiplodia*; and *Diplodiopsis*, which is a superficial, granulato-rugulose *Botryodiplodia*. With these last four this communication is not concerned, except that in so far as they are based on the older scheme of subdivision they are open to the same objections.

How this subdivision works in practice is best illustrated by the following example :—

In 1892, Patouillard (1) described *Botryodiplodia theobromæ*, on fruits of cacao from Ecuador. Its pycnidia are 200 μ diameter, more or less villous, united in a black villous stroma; the spores are brown, uniseptate, 25–35 × 12–15 μ; basidia hyaline, 50 μ long. A note in Saccardo adds "ad *Chætodiplodiam* vergit," but this does not appear in the original description.

In 1894, Prillieux and Delacroix (2) described *Macrophoma vestita* on the roots of cacao from Central America. Its pycnidia are 300 μ diameter, with hyaline, non-septate spores, 30 × 15 μ. The pycnidia are figured as simple and isolated.

In 1897, P. Hennings (3) described *Diplodia cacaoicola* on branches of *Theobroma cacao* from the Cameroons. Its pycnidia are scattered, immersed in the cortex; and its spores are 22–28 μ × 12–14 μ. This species was investigated by Howard in the West Indies, and from his account (5) we are able to add more details to Hennings' brief description.

Howard states that the rind of sugar cane is ruptured by the growth of dark bodies underneath, which are arranged in more or less vertical lines. These are colonies of true pycnidia, formed just beneath the rind, in connection with a dark-brown, septate, branched mycelium abundant in the tissues of the plant. His figure 11, which illustrates the growth of the fungus on cacao, shows four adjacent erumpent pycnidia in a basal weft of hyphæ. The pycnidia are said to contain

short conidiophores, 20–40 μ in length, and numerous paraphyses. When diseased pieces of sugar cane were placed in a moist chamber, it was observed that there was a considerable development of hairlike processes on the walls and round the opening of the pycnidium, giving the colonies a furry appearance which was never noted in the cane in ordinary circumstances. In plate and flask cultivations there was an enormous development of mycelium, forming a felt up to half an inch thick, in which the pycnidia were embedded. Howard states that the spores are very constant in size and measure 20 × 10 μ; in this respect his description of the fungus differs from that of Hennings. He was able to prove by cross inoculations that the *Diplodia* on sugar cane was identical with that on cacao.

In his discussion of the systematic position of the fungus, Howard writes: "In *Diplodia* the pycnidia are free from each other, occurring singly, and there is no stroma. In *Botryodiplodia*, they are arranged in colonies and a stroma is present. In considering the behaviour of the fungus under discussion under artificial conditions and on the host plants, it will be seen that there is a great variation in the arrangement of the pycnidia, as they sometimes occur alone, at other times in colonies. There is, besides, a good deal of variation in the amount and arrangement of the hyphæ surrounding the pycnidia. In some cases the latter appear to be embedded in a stroma, in others to stand in a web of hyphæ. It would therefore appear likely that the fungus on cacao pods in Ecuador (*i.e.*, *Botryodiplodia theobromæ*) is identical with that which is so common in the West Indies."

In March, 1906, Appel and Laubert (7) described the second known species of *Lasiodiplodia*, viz., *Lasiodiplodia nigra*, which was found on the lower parts of dead stems of *Theobroma cacao* and *Carica papaya* in Samoa. It formed black stromata, 2 to 4 mm. in diameter. The spores in the alcohol material measured 22 × 12 μ, but those developed in cultures were 28–32 × 18–21 μ. The stromata were pilose, and the pycnidia contained paraphyses.

In the same month, the present writer (9) published descriptions of two species of *Diplodia* which occur in Ceylon,

viz., *Botryodiplodia elasticæ* and *Chætodiplodia grisea*. *Botryodiplodia elasticæ* was found on *Hevea brasiliensis* and *Castilloa elastica*, and has since been discovered on *Ficus*, *Thea*, *Albizzia*, *Erythrina*, *Carica papaya*, and *Cocos nucifera*. In the case of *Hevea*, it was first found parasitic on young plants ("stumps") shortly after they had been planted out in the field. It burst through the cortex in linear or rounded masses up to 2 mm. diameter: these were largest when they emerged at the point of exit of the lateral roots. These masses were true stromata, and were glabrous. Higher up on the same stems, the pycnidia occurred singly or in groups, embedded in the bark. The pycnidia were 0·25–0·4 mm. in diameter, with spores 25–30 × 14–15 μ, and abundant paraphyses up to 80 μ long. The hyphæ of the fungus are at first hyaline, then violet black, but become brownish when old or when preserved in alcohol. The course of the hyphæ in fresh specimens is easily recognized by the long blackish streaks extending through the stem of the host. On young *Castilloa* which had been damaged by fire, the soft decaying bark was filled with masses of hyphæ which also ran, more or less free, over the surface of the wounds. In this case, the pycnidia were surrounded by loose hyphæ, and there was no solid stroma. The fungus has since been found to be an almost universal saprophyte on dead *Hevea* stems, but if the stems are not too damp, *e.g.*, when they have been lying in the laboratory for a fortnight, the pycnidia remain embedded in the bark, and there is no outward indication of their presence until the stem is covered with the extruded spores. In these cases the pycnidia may be united by a basal weft of hyphæ. In the soft, watery stems of *Carica papaya*, the loose weft of hyphæ is usually well developed, as in the case of *Castilloa* referred to above.

Appel and Laubert's description of *Lasiodiplodia nigra* was not available when the description of *Botryodiplodia elasticæ* was published, and even if it had been, it is doubtful whether, from the description, the Ceylon species would have been considered identical. Hennings' description of *Diplodia cacaoicola* does not mention the paraphyses (the most striking feature of the fungus), and Howard states that the spores of that

species are 20 × 10 μ: it seemed certain therefore that the Ceylon fungus was a different species, and as it did not agree with any of those described in Saccardo, it was considered new.

Diplodia cacaoicola had not been recorded for Ceylon prior to 1906, though the diseases of cacao had been under investigation for several years. In 1906, however, it was found to be fairly common on cacao in the Island, and on comparison with *Botryodiplodia elasticæ*, the two "species" were found to be practically identical, though *D. cacaoicola* has not been observed to form true erumpent solid stromata on cacao. This was recorded in the report of the Mycologist for 1906: "There seemed some probability that this fungus (*i.e.*, *Botryodiplodia elasticæ*) was identical with *Diplodia cacaoicola* Henn., which is parasitic or saprophytic on cacao, or at least with the *Diplodia* on cacao in Ceylon. The descriptions of *D. cacaoicola*, however, are contradictory, and our species does not agree with those of recent writers." It was hoped to decide this point by infections, but pressure of other work made this impossible.

Chætodiplodia grisea Petch was found on decaying cacao pods which had been kept moist. The pycnidia were scattered, and clothed with erect hairs. The spores measured 24–28 × 13–14 μ, and the fungus possessed long paraphyses.

A *Lasiodiplodia* has been recorded by V. K. Charles (6) as parasitic on *Theobroma cacao* and *Mangifera indica* in San Domingo, but apparently it has not been named. This record has given rise, in the West Indies, to the idea that there are two serious diseases of cacao there, one caused by *Diplodia cacaoicola* P. Henn., and the other by *Lasiodiplodia* sp.

Finally, in 1908, a *Chætodiplodia* was recorded by C. J. J. van Hall and A. W. Drost, as parasitic on cacao pods in Surinam (12).

From the descriptions briefly quoted above, the six fungi referred to are clearly all different. *Macrophoma vestita* has hyaline spores; *Diplodia cacaoicola* (according to Hennings' description) and *Botryodiplodia theobromæ* lack paraphyses; *Lasiodiplodia nigra* has spores which attain a *breadth* of 21 μ; *Chætodiplodia grisea* has pilose, scattered pycnidia; and the stromata of *Botryodiplodia elasticæ*, in its most highly developed

form, are glabrous. Yet, as the sequel shows, these names all refer to the same fungus!

This chaptor of errors has been partly corrected by Griffon and Maublanc (14). These authors had occasion to investigate a disease of cacao branches and roots from the Congo, and found in the diseased tissue a fungus with pycnidia either simple or grouped in a common stroma; its spores were ovoid and hyaline, and measured 25–30 × 12–15 μ. This was apparently *Macrophoma vestita*, though the pycnidia of the latter were figured as scattered. An examination of the type specimens, however, showed that the pycnidia were either scattered or grouped, and therefore this apparent difference vanished. Moreover, this re-examination proved that *Macrophoma vestita* is really a *Diplodia*, and a further comparison with the type specimen of *Botryodiplodia theobromæ* showed that it is identical with the last-named species. The supposed *Macrophoma* spores were immature *Diplodia* spores. As a result of this re-investigation, an additional character was added to the description of *Botryodiplodia theobromæ*, viz., that it possesses long paraphyses.

Griffon and Maublanc further conclude that *Diplodia cacaoicola* is the same species. From Howard's account and from the examination of this species in Ceylon, there is no doubt that their conclusion is correct: Howard's spore measurement is unaccountably small, and in this he is followed by Butler (8). They also regard Charles' *Lasiodiplodia* from San Domingo, and *Lasiodiplodia nigra* Appel and Laubert as identical with *Botryodiplodia theobromæ* Pat., both of which conclusions may be accepted.

Griffon and Maublanc's paper reduces three names to synonyms. A further reduction results from a paper by Brick (15). A consignment of young *Hevea* plants ("stumps") was forwarded from Ceylon to German West Africa, *viâ* Hamburg. They were packed in latticed cases, with their roots embedded in damp coconut fibre and earth. On arrival in Hamburg, 87 per cent. of the plants were found to be dead, and the remainder were diseased. Brick, who examined them in Hamburg, found a *Lasiodiplodia* on the dead plants. This he considers is *Lasiodiplodia nigra*, and is identical with

Botryodiplodia elasticæ Petch. From the nature of its occurrence, and the full description given by Brick, there is no doubt that the fungus is *Botryodiplodia elasticæ*, and as he is presumably acquainted with *Lasiodiplodia nigra*, his conclusion as to the identity of these two must be accepted. The Hamburg specimens differ from those recorded from Ceylon in their larger stromata, up to 5 mm. in diameter, embedded in a loose weft of hyphæ, whereas the compact stromata in Ceylon are glabrous. But this difference is just what might be expected if the stromata developed in a constantly damp situation.

A re-examination of the type specimen of *Chætodiplodia grisea* Petch, in the light of the experience gained during the last four years, has convinced me that this is merely *Botryodiplodia theobromæ*, with scattered pycnidia, clothed with hairs as a consequence of its development in a saturated atmosphere. Similarly, A. E. van Hall (18) has arrived at the conclusion that the *Chætodiplodia* sp. recorded on cacao pods in Surinam is only *Diplodia cacaoicola*, *i.e.*, *Botryodiplodia theobromæ*.

As a result of these re-investigations, we must accept the following synonymy :—

Botryodiplodia theobromæ Pat. (1892).

= *Macrophoma vestita* Prill. & Del.	(1894)
= *Diplodia cacaoicola* Henn.	(1895)
= *Lasiodiplodia nigra* Appel et Laub.	(1906)
= *Botryodiplodia elasticæ* Petch.	(1906)
= *Chætodiplodia grisea* Petch.	(1906)
= *Lasiodiplodia* sp. Charles.	(1906)
= *Chætodiplodia* sp. Van Hall & Drost.	(1908)

It is scarcely necessary to point out the important bearing which this confusion has upon practical mycology in the tropics. We have been compelled to believe that our cacao diseases were more numerous than those of any other plant cultivated in the tropics, and that each cacao-growing country had its own peculiar parasitic *Diplodia*. The diseases of cacao have recently been monographed by F. C. von Faber (16): in this work nine pages are devoted to the discussion of these Diplodias and their treatment, under the belief that they are all different. Owing to the erroneous descriptions and

incorrect identifications of tropical fungi, the diseases of the same plant in different countries are considered quite distinct, and thus the work of a mycologist in one country is thought to be inapplicable to the diseases of another. In actual fact, it is being abundantly demonstrated that plant diseases are identical throughout the tropics, but this state of things has not yet been hitherto perceived for the reasons already mentioned. Even in the same country, an erroneous determination of a known species is liable to cause serious alarm. In the West Indies, for example, the *Diplodia* on cacao has long been known under the name of *Diplodia cacaoicola*. But quite recently, in ignorance of the fact that it was the same thing, a scare has been raised by the discovery on cacao of a *Lasiodiplodia* to whose agency diseases of all descriptions have been attributed.

The distinctions between the various subdivisions of the Sphærioidaceæ-Phæodidymæ are by no means clearly understood. Brick (*loc. cit.*) states: "The genus *Botryodiplodia* Sacc. differs from *Lasiodiplodia* Ell. & Ev. in the absence of the paraphyses in the hymenium." This is scarcely correct. The distinguishing features of *Lasiodiplodia*, as given by its authors, are three, viz., the formation of a stroma, the presence of paraphyses, and the weft of hyphæ surrounding the stroma; and would appear from the name that the latter character was considered the most important. Ellis and Everhart have erred in laying special stress on the occurrence of paraphyses. The presence of paraphyses alone has never been considered a subgeneric character, either before or after the institution of *Lasiodiplodia*. Thus, we have, prior to *Lasiodiplodia*, *Diplodia cococarpa* Sacc., *D. nematospora* Sacc., *D. cactorum* Speg., *D. gongrogena* Temme., *D. guaranitica* Speg., *D. nutans* Speg., *D. ægyptiaca* F. Tassi, *D. paraphysaria* Sacc.; and subsequently, *D. paraphysata* Ell. & Ev., *D. zeylanica* F. Tassi, *D. arthrophylli* Penz. & Sacc., *D. Mangiferæ* Koorders, *D. Wurthii* Koorders, *D. cinchonæ* Koorders, *Chætodiplodia coffeæ* Zimm., *Chætodiplodia vanillæ* Zimm., all with long paraphyses. Of these, *Diplodia paraphysata* Ellis & Everhart is most instructive: it was described in 1897, a year after *Lasiodiplodia tubericola* Ell. & Ev.;

its pycnidia are pilose, scattered or subconfluent, with long internal paraphyses; yet its describers do not consider that it falls within their genus *Lasiodiplodia*. It has two of the characters of that genus, but its pycnidia are not embedded in a true stroma. After this example, we may be quite certain that most of the forms of *Botryodiplodia theobromæ* Pat. would not be considered as *Lasiodiplodia* by the authors of that genus. Nor would *Lasiodiplodia Thomasiana* Sacc., whose pycnidia are "modo solitariis, modo paucis coacervatis."

Bancroft (24) falls into the same error as Brick. In discussing *Botryodiplodia theobromæ*, he states: "But these authors all overlook the presence of paraphyses in the pycnidia, on account of which the fungus must be regarded as a *Lasiodiplodia*." Reference to the characters of the genus will show that this is incorrect, and *Diplodia paraphysata* proves that it was not the authors' idea of their genus. The distinguishing character of *Lasiodiplodia* is the pilose stroma.

The above list of Diplodias which possess paraphyses is in all probability far from complete. Many of the older descriptions include measurements of "basidia," and it appears probable that in some cases these may have been paraphyses. For example, the "basidia" of Patouillard's *Botryodiplodia theobromæ* must have been paraphyses. If the presence of paraphyses is to be considered of subgeneric importance, we are at once beset with difficulties. It would not be at variance with the information available at present, if we were to suppose that very many, if not all, species of *Diplodia* are furnished with paraphyses, but that these attain a length greater than that of the basidium plus its spore only in tropical species. It would be necessary to decide whether a given filament were a paraphysis, or a basidium deprived of its spore, and this would give occasion for endless differences of opinion. The difficulty might be evaded by counting as paraphyses only those filaments which exceeded the length of a basidium plus its spore, but the distinction would be purely artificial, corresponding to that between *Diplodia* and *Microdiplodia*.

The present classification of the Sphærioidaceæ-Phæodidymæ is given in the following table :—

A.—Pycnidia isolated, stroma wanting.	
(*a*) Pycnidia innate or erumpent.	
* glabrous.	
† spores destitute of mucus.	
§ spores exceeding 15 μ	*Diplodia* Fr.
§§ spores less than 15 μ	*Microdiplodia* Alles.
†† spores large, surrounded by mucus	*Macrodiplodia* Sacc.
** pilose or setose.	
† without a rostrum	*Chætodiplodia* Kars.
†† with a rostrum	*Rhynchodiplodia* Br. et Farn.
(*b*) Pycnidia superficial, or sub-superficial.	
† without a rostrum	*Diplodiella* Karst.
†† with rostrum	*Pellionella* Sacc.
B.—Pycnidia united into a stroma.	
(*a*) Stroma glabrous	*Botryodiplodia* Sacc.
(*b*) Stroma pilose	*Lasiodiplodia* Ell. & Ev.
(*c*) Stroma granulato-rugulose	*Diplodiopsis* P. Henn.

This key appears quite definite, but in practice it proves quite unworkable. Brick places the species under discussion in *Lasiodiplodia*, as his specimens were furnished with a stroma, clothed with hyphæ: and as far as his specimens permitted him to judge, his view was quite correct. But it must be remembered that they had been developed under abnormal conditions. Griffon and Maublanc also place this fungus in *Lasiodiplodia* under the name *Lasiodiplodia theobromæ* (Pat.) Griff. et Maubl., but it would appear doubtful, from their figures, whether the pycnidia were contained in a true stroma. On the other hand, Hennings decided that it was a simple *Diplodia ;* and Howard was of opinion that the fungus should stand as a simple *Diplodia*, not as a *Botryodiplodia*. Butler, however, states that in its natural habitat in Bengal on the sugar cane the fungus must be considered a *Botryodiplodia*, not a *Diplodia*.

If we collect the opinions of those mycologists who are known to have examined this fungus, we find that seven have considered it a simple *Diplodia*, three a *Chætodiplodia*, three a *Botryodiplodia*, and six a *Lasiodiplodia*. If, however, we consider only the independent determinations of the fungus, the number of times it has been assigned to *Lasiodiplodia* is only four, and in none of these four cases has the determination been based on an examination of material in the country of origin.

These differences of opinion cannot be attributed to any fault on the part of the describers. Each classifies the fungus according to the form he happens to have. On *Hevea* stems and cacao branches it is usually a simple *Diplodia*, often united into groups by a basal weft of hyphæ; as Howard decided, one is scarcely justified in placing it anywhere but in *Diplodia* on such material. On cacao and *Hevea* pods it is either simple or grouped, and here it might sometimes be assigned to *Botryodiplodia*, though there is no true stroma, and the pycnidia are best described as subconfluent. When the pycnidia have developed on cacao pods in a saturated atmosphere, they are distinctly pilose, and if scattered they cannot be referred to any group but *Chætodiplodia*. When the fructification emerges from the points of origin of the lateral roots of young *Hevea* plants, it is an undoubted *Botryodiplodia*, with a glabrous solid stroma; but under exceptional conditions this stroma may be surrounded by hyphæ (*fide* Brick), and it is then a *Lasiodiplodia*.

It is evident from this example that the present system of subdivision of the genus *Diplodia* is, in part, based upon characters which are not constant. The primary groups, viz., simple Diplodias and Diplodias united into a stroma, are not mutually exclusive. A *Botryodiplodia* may form isolated pycnidia and grouped subconfluent pycnidia as well as true stromata. However, this division might stand, if it is extended to mean that the first group includes those Diplodias which never form a stroma, while the second includes those which sometimes form a stroma and sometimes scattered pycnidia. But under these circumstances, the correct determination of a species would involve a more extensive examination of material than is at present customary.

More serious objections can be urged against the subgenera *Chætodiplodia* and *Lasiodiplodia*. A *Chætodiplodia* is a pilose simple *Diplodia*, while a *Lasiodiplodia* is a pilose *Botryodiplodia*. But if *Diplodia cacaoicola*, *i.e.*, *Botryodiplodia theobromæ* in its simple form, is grown on a cacao pod in a damp chamber, it becomes a *Chætodiplodia*, while if the *Botryodiplodia* form is grown under equivalent conditions it becomes *Lasiodiplodia*, as in Brick's specimens. From the example afforded by *Botryodiplodia theobromæ*, it is evident that *Chætodiplodia* and *Lasiodiplodia* are based on characters which are due to environmental factors, either growth in a more or less saturated atmosphere or on a substratum amply provided with moisture. They ought therefore to be discarded, *Chætodiplodia* being thrown into *Diplodia* and *Lasiodiplodia* into *Botryodiplodia*, the latter subgenus being amended as suggested. On the same grounds, *Rhynchodiplodia* should presumably be referred to *Pellionella*. Nothing would be lost by this sacrifice, since species of these supposed subgenera are only rarely recognizable as such. *Chætodiplodia* might be retained for those species, if any there be, which bear true setæ on the pycnidium wall.

Van Hall and Drost (18) have already arrived at similar conclusions. They state "as the hairlike processes of the pycnidia (*i.e.*, of *Botryodiplodia theobromæ*), the characteristic by which *Chætodiplodia* is distinguished from *Diplodia*, is not constant but results from definite conditions, the genus *Chætodiplodia* must be annulled and joined to the genus *Diplodia*." "Sometimes in diseased branches or pods the pycnidia appear in groups, sometimes they stand isolated. As this appearance in groups, the distinguishing character of the genus *Lasiodiplodia*, is not constant, the genus *Lasiodiplodia* must also be cancelled and joined to the genus *Diplodia*." The adoption of Van Hall and Drost's suggestion would involve the abandonment of the subgenus *Botryodiplodia* also. There is much in favour of such a course, since, without a large quantity of material, a *Botryodiplodia*, as at present understood, is not always recognizable. This is quite evident from the records of *Botryodiplodia theobromæ*. But it would seem preferable to refer *Lasiodiplodia* to *Botryodiplodia*, and

admit that the species in the latter subgenus may form isolated pycnidia as well as stromata.

The present writer's opinion has been expressed (17) as follows: "*Botryodiplodia elasticæ* affords another instance of the multiplication of names which results from the transmission of specimens of tropical diseases to Europe. Species of *Diplodia* occur everywhere in the tropics, on all kinds of plants, and the majority of them are merely saprophytic, *i.e.*, they grow only on dead tissues. If a *Diplodia* occurs in masses, it is known as *Botryodiplodia*, and if the masses are surrounded by loose hyphæ, it is known as *Lasiodiplodia*. But, unfortunately, these apparent distinctions break down in practice, for the same species may exhibit all three forms. In that case, it usually gets three different names, according to the form which each describer happens to have. *Botryodiplodia* is a convenient name for those species which may sometimes grow in masses and sometimes singly, and distinguishes them from those species which always grow singly, but *Lasiodiplodia* is a purely herbarium distinction for which we have no use in practice."

The adoption of the views enunciated above would reduce the classification to the following :—

A.—Pycnidia isolated, stroma wanting.

(*a*) Pycnidia rostrate.
§ pycnidia superficial — *Rhynchodiplodia.*
§§ pycnidia sub-superficial — *Pellionella.*

(*b*) Pycnidia not rostrate.
§ pycnidia innate or erumpent.
† spores exceeding 15 μ — *Diplodia.*
†† spores not exceeding 15 μ — *Microdiplodia.*
††† spores large, surrounded by mucus — *Macrodiplodia.*
§§ pycnidia sub-superficial, lignicolous — *Diplodiella.*

B.—Pycnidia sometimes united into a stroma, sometimes isolated — *Botryodiplodia.*

It may be noted that there is only one species in each of the subgenera *Rhynchodiplodia* and *Pellionella*, and that practically only the pilose character of the former separates them; as this character has been proved inconstant in other

Diplodias, their separation is doubtful. *Diplodiopsis* P. Henn., if it has no more distinctive characters than "superficial, granulato-rugulose," cannot be separated from *Botryodiplodia*; both characters may be found in the specimens of *Botryodiplodia theobromæ* which develop from the points of origin of the lateral roots of young *Hevea*.

Diplodia Wurthii Koorders appears to furnish a further example in support of the above conclusions. This species was discovered on leaves and stems of *Ficus elastica* in Java. Its pycnidia are scattered or gregarious, sometimes confluent, 150–250 μ diameter; the spores measure 22–30 × 12–18 μ, and it has paraphyses 50–60 μ long. Koorders states (11) that the pycnidia which develop on nutrient media exhibit a development of hairs at the apex in some cases. He relates how, when a dead leaf of *Ficus elastica* which bore several pycnidia was left wrapped up in a damp cloth for several days, numerous pycnidia clothed with a thick growth of hairs developed on the under surface. These hairs developed from the apex and the upper part of the wall of the pycnidia, as well as from a black stroma, and formed a web of hyphæ; they originated beneath the epidermis, but subsequently broke through and became chiefly superficial. Koorders notes that if the non-pilose form were not known, these specimens might have been referred to *Lasiodiplodia* or *Chætodiplodia*. But since the black web of mycelium and the remarkable stroma-like structure of the pycnidia are only the result of the changed external conditions, he considers that the fungus should be referred to *Diplodia*. The behaviour of this species is identical with that of *Botryodiplodia theobromæ*. It must, however, be pointed out that in all probability this example does not really afford *additional* evidence in favour of the general conclusion that *Lasiodiplodia* and *Chætodiplodia* are founded on inconstant characters, for it is in the highest degree probable that *D. Wurthii* is identical with *Botryodiplodia theobromæ*. The latter grows abundantly on dead *Ficus elastica* in Ceylon.

As we have already seen, the presence of paraphyses in the hymenium has never been considered a character of sufficient importance to warrant the separation in distinct subgenera

of those *Diplodias* which possess them. Ellis and Everhart's generic description of *Lasiodiplodia* is incorrect in laying special stress on this point, since species with and species without paraphyses are, according to the accepted practice, included indiscriminately in each subgenus. The distinguishing character of *Lasiodiplodia* is the pilose stroma. But the presence of paraphyses might be used as a character by which to split each of the present subgenera, if further investigation should prove that paraphyses are really absent from those species in which they have not been recorded. It is evident that our information on this point is at present insufficient. The paraphyses have been overlooked even in species in which they are specially well developed, as is illustrated by Hennings' description of "*Diplodia cacaoicola.*" It may be noted that Koorders (*loc. cit.*) records that in *Diplodia Wurthii* the basidia and spores are formed before the appearance of the paraphyses.

Griffon and Maublanc accept the subgenus *Lasiodiplodia*, and have therefore named the species under discussion *Lasiodiplodia theobromæ* (Pat.) Griff. & Maubl. But in view of the fact that the genus *Lasiodiplodia* is based on a character which is entirely dependent upon external conditions, it would seem preferable to abandon it, and keep Patouillard's name, *Botryodiplodia theobromæ*, for this fungus.

Two other inconstant characters which often find a place in descriptions of Diplodias may be referred to here. Longitudinal striping of the spores, frequently a most striking feature, may be present or absent, not only in spores of the same species, but even on spores from the same specimen. Further, the colour of the spores of the same species varies according to the age of the spore, but apparently each shade of colour may persist for a long time under certain conditions. For example, spores of *Botryodiplodia theobromæ* extruded from fresh specimens may be hyaline, dark gray, blackish-gray, or violet-black, but in old specimens and material preserved in alcohol they are brown or blackish-brown.

Botryodiplodia theobromæ Pat. has been found in Ceylon on fruits and stems of *Theobroma cacao*, on fruits and stems of *Hevea brasiliensis*, on fruits and roots of *Cocos nucifera*, on the

roots and stems of *Thea*, on surface roots of *Ficus elastica*, on stems of *Castilloa elastica*, *Albizzia moluccana*, *Erythrina lithosperma*, and *Carica papaya*. Brick records it on decaying fruits of *Latania borbonica* from Venezuela. V. K. Charles found what is probably the same species on fruits of *Mangifera indica* from Florida, and on fruits and stems of cacao from Brazil and San Domingo. Appel and Laubert recorded it on *Cacao* and *Carica papaya* from Samoa. Howard on cacao and sugar cane in the West Indies, Griffon and Maublanc on cacao from the Congo and *Albizzia moluccana* from Madagascar, Butler on sugar cane in India, while Hennings, Prillieux and Delacroix, Patouillard, and van Hall and Drost have found it on cacao in the Cameroons, Central America, and Surinam. It will be noted that these records are diametrically opposed to the belief which has apparently been held by describers of fungi, viz., that Diplodias on different host plants must be different species.

Griffon and Maublanc suggest that *Lasiodiplodia tubericola* Ell. & Ev., the original species of *Lasiodiplodia*, may be identical with *Botryodiplodia theobromæ* Pat.; its spores are given as 18–22 × 11–14 μ, *i.e.*, about one-third shorter than those of the latter species. *Lasiodiplodia Thomasiana* Sacc., with spores 28–30 × 11–12 μ and paraphyses 80–90 μ long, on leaves of *Heptapleurum Barteri* from S. Thome (13), would appear to be *Botryodiplodia theobromæ*. There does not seem much room for doubt that *Diplodia Wurthii* is *Botryodiplodia theobromæ*, and in all probability the same is true of *D. mangiferæ* Koorders and *D. cinchonæ* Koorders. The descriptions of these last three species do not reveal any striking points of difference, and it would seem that their author had been influenced chiefly by the fact that they grew on different hosts. A search through Saccardo shows that there are many species, anterior to *Botryodiplodia theobromæ*, which should be compared with it, to determine whether they are not the same. For example, on *Carica papaya* there is *Diplodia papayæ* Thüm., with spores 25 × 10 μ. Again, on *Cocos nucifera* we have *Diplodia cococarpa* Sacc., with spores 22 × 12 μ and long paraphyses, *Diplodia epicocos* Cooke, with spores 22 × 10–12 μ, *Diplodia palmicola* Thüm., with spores 20 × 10 μ.

and *Chætodiplodia diversispora* March., with spores 25–33 × 13–15 μ.

Recently Ridley (20) has recorded a new fungus disease of *Hevea brasiliensis* in the Federated Malay States. The fungus attacked the shoots and worked down the stem until the tree was killed. In some places a black fungus was found emerging from the cracks in the bark, and on the older parts of the branch the bark was covered with larger elevated patches, black in colour and looking as if soot had been thrown on the tree. Ridley states that the perithecia are embedded in a black stroma and that the spores are oval and transversely divided, but he refers the fungus to *Cucurbitaria*. The disease is said to be a rapid one, killing two-year old trees almost down to the base in twelve days; but this record is uncertain, since the tree was thought to be "wintering" when first observed. Subsequently, the same fungus was recorded (21) from Selangor: in this case it attacked stumps about 3 inches in girth, and killed 80 per cent. of them.

The symptoms described by Ridley are exactly those of the "dieback" and stump disease caused, in Ceylon, South India, and Burma, by *Botryodiplodia theobromæ*. The fungus has, however, been described by Massee (23) as *Diplodia rapax*—"Perithecia 3–7 aggregata, globosa atra, primo tecta, dein erumpentia, rugulosa, glabra, 160–180 μ diametro, ostiolo minuto vix stromatis superficiem attingente donata. Sporæ ærogenæ, ellipticæ, utrinque obtusæ, medio 1-septatæ, haud constrictæ, opace fuligineæ, 32–35 × 15–16 μ." Massee (22) suggests that it is a stage in the life cycle of some species of *Rosellinia!* The fungus was received at Kew, almost at the same date, from Singapore and the Gold Coast, and it is suggested (23) that it "has been conveyed along with the seed, as it is difficult to realize that the same species of fungus can have adapted itself to rubber trees in two distant countries, and within so short a period of time."

From the descriptions, it would appear that the fungus should have been described as a *Botryodiplodia*. Its spores are not larger than those of *Botryodiplodia theobromæ* as measured by Patouillard. There is no mention of any paraphyses, but this apparent difference may be, as usual, an oversight. It is in

the highest degree probable that *Diplodia rapax* is the same as *Botryodiplodia theobromæ*. It would be strange indeed if a fungus which is known to grow on *Hevea* in Ceylon, South India, Burma, and Java, and which is known to be common throughout the tropics, did not occur in Malaya. On that supposition, its occurrence on *Hevea* on the Gold Coast, a cacao-growing country, is only to be expected. But in spite of its apparent abundance, I have not been able to obtain a specimen of *Diplodia rapax*, either from Kew or Malaya, and therefore this point remains undecided.

The opinions which have been expressed as to the parasitism of *Botryodiplodia theobromæ* have been for the most part based on an examination of preserved specimens in Europe, and under those circumstances they are of doubtful value. The fungus is a widespread saprophyte, and is seldom absent from dead *Cacao* or *Hevea* material: and as it is the most evident fungus on the specimens sent to Europe, all kinds of diseases are attributed to it. No sound pathological work can result from such conditions of investigation, and frequently such work occasions totally erroneous views of the situation. For example, every book which treats of the diseases of tea refers to the serious leaf disease caused by *Pestalozzia guepini*: yet, apart from the fact that the fungus is really *P. palmarum*, this disease occurs everywhere in tea in Ceylon and does so little damage that no steps have ever, to my knowledge, been taken to combat it. When the leaves of a tea bush wither, the planter (as a rule) gathers them and sends them as samples of the disease; and it would be remarkable if none of the older leaves exhibited the gray patches caused by *Pestalozzia*. But the bushes may be really suffering from an attack of root disease, of which the withering of the leaves is only a secondary symptom.

Brick states that *Botryodiplodia theobromæ* is a dangerous parasite of *Hevea*, *Castilloa*, and *Cacao*. In the West Indies, most of the diseases of cacao have been attributed to *Botryodiplodia theobromæ*, though Howard's experiments only show that it is a wound parasite, and can attack picked pods if they are wounded. In Surinam, van Hall and Drost, working on the spot, have decided that "The dieback disease of cacao

trees is caused by a fungus (*i.e.*, *Botryodiplodia theobromæ*) which also causes the 'brown rot' of the pods. The die-back disease only affects trees which by some cause (Thrips, witch broom disease, wind, sudden want of shade) are in a leafless or in a nearly leafless condition. The fungus does not affect healthy pods, but causes decay of picked pods, or pods which by some cause or other are wounded, or which have already been attacked by other fungi." Experience in Ceylon agrees completely with the foregoing. "Dieback" of cacao occurs when the shade has been removed and the twigs killed by the sun, or when they have been severely attacked by *Helopeltis*; the *Diplodia* then develops on the dead tissues, and may kill off the branch still further. Cacao pods develop *Botryodiplodia* if they have been attacked by other fungi, or if they are picked and stored. There is no doubt that *Botryodiplodia* is a secondary fungus in diseases of cacao. The name "brown rot" is an unfortunate one, for in the early stages of the disease caused by *Phytophthora faberi*, the diseased parts of the pod are clear brown.

On *Castilloa*, *Botryodiplodia* has been observed in Ceylon as a wound parasite only: it attacked young trees which had been damaged by fire. On *Carica papaya* it has been found, in Ceylon, only on felled stems. On *Erythrina lithosperma*, it is a wound parasite. On *Albizzia moluccana* it is also a wound parasite, entering the stems after they have been pruned. It is a most common saprophyte on *Hevea brasiliensis* and *Ficus elastica*, and if healthy stems of either are cut down and left lying on the laboratory verandah, they will develop this fungus within a fortnight. But it is a wound parasite in *Hevea* "dieback," as in the similar disease of cacao, and in this case it may kill the tree entirely. It occurs as a saprophyte in *Hevea* and cacao bark which has been killed by "canker." Its exact status in the case of young *Hevea* plants and of tea is somewhat uncertain. In the former, it may only attack the "stumps" through injuries inflicted during the planting out, while they are more or less dormant, but, as it is known to have killed "basket plants," it would appear probable that it can live as a soil fungus and attack the roots directly. Tea is undoubtedly attacked through

the roots, but whether only after they have been injured has not yet been ascertained.

On the whole, though *Botryodiplodia theobromæ* is extremely widely spread, it has caused comparatively little damage, and it is impossible to resist the conclusion that in the majority of instances it is only saprophytic. Koorders concludes, as a result of his infection experiments, that *Diplodia Wurthii* is a saprophyte which in rare cases can function as a wound parasite.

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Thielaviopsis paradoxa (de Seynes) v. Höhnel.

BY

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Thielaviopsis paradoxa was first found by de Seynes, on pineapples in France, and was described by him under the name *Sporochisma paradoxum* in 1886. Subsequently it was discovered, parasitic on sugar cane in Java, by F. A. F. C. Went, who re-described it as *Thielaviopsis ethaceticus.* As the cause of disease in sugar cane, it has since been studied by Howard, Massee, Prillieux and Delacroix, Cobb, Lewton Brain, and Butler, all of whom refer to it under Went's name. v. Höhnel found it growing on coconut in Vienna, and showed that Went's fungus was identical with that described by de Seynes. Recently it has been found to be the cause of a stem disease of the coconut palm in Ceylon; and as it has been under investigation for some considerable time, it has been thought advisable to summarize the observations of previous authors, and to indicate how far they agree with observations made in this country.

de Seynes.

As stated above, de Seynes (3) found his fungus in pineapples, and, contrary to the experience of subsequent investigators, he was not able to grow it on other fruits. The affected pineapples showed, in longitudinal section, a black patch, which evidently originated towards the exterior of the fruit. In advanced cases this patch sometimes extended to, and involved, the bases of the leaves which crown the fruit. (This last observation is in opposition to that of Cobb, but it may be explained on the supposition that de Seynes examined cut fruits only.) From the black patch, especially from its margin, there emerged a white mould, continuous with the mycelium which caused the stain.

The mycelium of the fungus is described as slender, slightly branched, hyaline, and thin-walled, with septa 25–40 μ apart.

Its diameter was only 2–3 μ, though de Seynes found some branches up to 6 μ diameter, which he regards as arrested sporophores. (This diameter is very much smaller than that observed in Ceylon.)

The sporophores were erect and fusiform, and stouter than the mycelium. They appeared first as small spherical prominences which were cut off by a septum a little above the point of origin. Thence they increased suddenly in diameter to 8 or 10 μ, after which they diminished gradually to a diameter of about 5 μ. Their total length was 100–150 μ, and their colour, especially towards the base, was reddish-brown or fuliginous. They possessed two to four septa near the base. Branched sporophores were not rare.

The conidia were one-celled, hyaline, cylindric, truncate or rounded at the extremities, 4–5 μ in diameter, and 5–8 μ in length. Sometimes they separated from one another, sometimes several remained united in a chain, but those formed last issued freely from the interior of the sporophore. de Seynes understood that the spores were formed in succession within the sporophore, but he appears to have believed that those first formed were united to the wall of the spore cell, and broke away with part of the latter, while those formed later were formed free in the cell, and therefore after their expulsion part of the wall of the latter remained as an empty tube. This, and other examples, serve as a basis for his paper on acrogenous conidia (2).

In addition to the conidia described above, the same mycelium bore other conidia, which de Seynes named *Macroconidia.* They occurred singly, or in chains of two or three, on branches less specialized than the sporophores previously described. These conidia were oval, rarely spherical, 10–22 × 7–10 μ, olivaceous brown, black in mass. They are said to be segmented off from the parent cell, but endogenous, and to be set free by the destruction of the upper part of the cell wall of the parent cell. It is extremely doubtful from this description whether de Seynes really observed the perfect formation of what are now known as Macroconidia.

He notes that among the conidia developed from the special sporophores (*i.e.*, those now known as microconidia) one often

finds examples which have assumed the colour, and sometimes the form, of the macroconidia. Further, when his cultivation was old, he found that groups of erect sporophores were produced, resembling the stalks of an *Isaria* or *Stysanus*, in which each microconidiophore retained its individuality. (This formation has not been recorded by any subsequent investigators, though it is quite easily obtained.)

F. A. F. C. Went.

Went's first accounts of *Thielaviopsis ethaceticus*, and its effect upon sugar cane, were published in agricultural journals which I have not been able to consult. The following description is taken from his article in the Annals of Botany (8).

Went states that the conidia soon germinate in any nutrient solution, and the cultures remain snowy white as long as only vegetative mycelium is developed, but that in from twelve to twenty-four hours they become olive-green or dark green, owing to the formation of conidia. He was able to grow the fungus on mangoes, pineapples, bananas, &c., and states that it will grow on all sorts of materials containing sugar. (In my experience, the change of colour takes place *after* the formation of microconidia, when the macroconidia begin to appear.)

The conidiophore which produces microconidia (de Seynes' specialized conidiophore) is at first a thick, somewhat curved branch of the mycelium, which lengthens into a regularly tapering cell, 100-200 μ in length, in which the conidia are developed, and from which they are ejected in a continuous chain. These microconidia are rectangular, and measure $10–15 \times 3 \cdot 5–5\ \mu$: as a rule they are colourless; but sometimes they are slightly coloured and more oval, thus resembling to some extent the macroconidia.

The macroconidia are situated in chains at the ends of short branches of the mycelium: they are dark olive-green, and measure $16–19 \times 10–12\ \mu$. The conidium at the top of the chain is often almost spherical, but the remaining conidia are more elongated. According to Went, the first macroconidium is formed by the growth of a septum across the hypha, a short distance below the apex: soon afterwards a second is produced by the growth of another septum below

the first ; and the process continues until a chain of conidia is produced. The macroconidia are therefore produced in a basipetal manner and are not endogenous. (It is now generally admitted that this observation is incorrect.)

Went states that the size of the macroconidia, and that of the microconidia too (but in a less degree), is extremely variable, so that the measurements given are only approximately true. Macroconidia and microconidia may be produced on branches of the same mycelial filament ; and in cultures started with either form, both kinds of conidia are produced. He also considers that both macro- and micro-conidia may occur in the same chain, and he figures a case in which the first three conidia are macroconidia, formed basipetally, while the fourth is a microconidium formed within the hypha. (But there is no doubt that this observation is incorrect, and that he was mistaken in his idea of the mode of formation of the macroconidia.)

As the result of various cultures, Went concludes that the fungus can invert dextrine and saccharose into glucose, can make ethylic alcohol out of glucose, and finally can oxidize this alcohol to acetic acid. The odour of pineapples, which it causes in diseased sugar cane, is due to the formation of ethyl acetate. Went observes that the odour disappears from old cultures of the fungus, so that it is probable that ethyl acetate may be assimilated by *Thielaviopsis*.

Went's figures in the Annals of Botany are still the most accurate that have been published of this species.

Massee.

Massee obtained his material from the West Indies, and cultivated the fungus at Kew. The nutrient solution employed was a decoction of sugar cane. His account is complicated by the introduction of two other species, *Trichosphæria sacchari* and *Melanconium* sp. He considered that the *Thielaviopsis* and the *Melanconium* were stages in the life history of the *Trichosphæria*, but it is now generally admitted that this view is doubtful. The *Melanconium* is common on sugar cane in the West Indies, but the *Trichosphæria* is apparently rare.

Massee states (6) that the microconidiophore when mature is pale gray, sparingly septate, and from 150 to 220 μ in length; it is swollen to a breadth of 12 to 16 μ at a short distance from the base, and gradually tapers to the apex, where it is about 6 μ in diameter. The conidia were developed in a chain at the ruptured apex of the conidiophore "in a manner precisely similar to the macroconidia": they were elliptic-oblong with truncate ends, of a clear pale reddish-brown in colour at maturity, and measured on an average 10–11 × 6 μ. The number of conidia in a chain rarely exceeded ten, and the terminal conidium was of the same shape as the rest, not spherical as in the case of the macroconidia.

The macroconidia were produced on short lateral branches. The top of the branch swelled out until it was about twice the diameter of the hypha, its apex was dissolved, and some of the protoplasm extruded. This mass of protoplasm then acquired a cell wall. Succeeding conidia were formed in the same way until a chain of fifty or more was produced. The wall of a conidium was at first colourless; in about twelve hours it had become tinged with clear olive-green; in twenty-four hours it was sooty-brown; and finally opaque blackish-brown. The terminal conidium was always spherical, and measured 24–26 μ in diameter, but the remainder were barrel-shaped, with truncate ends, and measured 18–20 × 12 μ.

It is difficult to harmonize these observations with those of other observers. The microconidia are produced in long tapering tubes, and the macroconidia on short lateral branches; but eighty or more microconidia may be produced from one conidiophore, while the chain of macroconidia usually does not contain more than ten. The microconidia are at first almost exactly rectangular in outline, and they are formed *within* the tube; they usually remain colourless for so long a period that many investigators have described them as permanently colourless. The macroconidia, on the other hand, are formed by the extrusion of protoplasm, and therefore assume a spherical or elliptical shape; and they rapidly become almost black. The apparently swollen apex of the macroconidiophore is the first extruded mass of protoplasm.

From Massee's figures of spores (6) one would judge that he had seen *macroconidia* only; but from the figures of conidiophores, it would be supposed that he had seen only *microconidiophores*. The figures of the latter, however, bear very little resemblance to the elegantly tapering tube of the reality; and I have never been able to observe a flaring mouth as there depicted. Went, who also obtained material from the West Indies, states that the *Thielaviopsis* on sugar cane there is identical with that found in Java; so the supposition that Massee worked with a different species is improbable.

Throughout his article Massee regards the microconidia as aerial, and the macroconidia as formed only within the tissues of the host, or, in the case of liquid media, beneath the surface of the liquid. Hence he writes with regard to the microconidia: "This form of reproduction is a modification of the one last described (*i.e.*, the macroconidium), developing from the same hyphæ, and owing its structural peculiarities to exposure to light and air during growth: thus illustrating from an unexpected quarter a general rule amongst groups of fungi showing a transition from a subterranean to an aerial condition ...... In the present instance, the advance made in the general structure of the microconidia over the macroconidia tends in the direction of favouring the dispersion of the conidia by wind; the entire fructification is developed in the air, the conidiophores are elongated, and the conidia are comparatively minute." It will be shown later that this explanation is based upon incomplete observations.

The supposed genetic connection between the *Melanconium*, *Thielaviopsis paradoxa*, and *Trichosphæria sacchari* was considered to be established by the following experiments:—In one flask, out of three in which *Melanconium* conidia were sown, microconidia of *Thielaviopsis* developed after twelve days. Nothing of the kind developed in hanging drops, in which the whole course of development could be watched, and the *Melanconium* conidia were evidently obtained from an impure source, *i.e.*, from ordinary diseased sugar cane; under such circumstances, the evidence of a single culture from uncontrolled spores is scarcely sufficient. A second

flask culture, which had been started with a single (?) macro-conidium of *Thielaviopsis*, and contained an abundance of macro- and micro-conidia, was put aside for an unstated period. The flask was subsequently broken by accident, and on examination there were found "two young perithecia, almost colourless and without fruit, but bearing the long characteristic bristle-like septate hyphæ, present on the mature perithecia (of *Trichosphæria sacchari*) found on the decayed cane; two examples of the initial stage of a perithecium were also found." The initial stage of a perithecium, as figured, bears much resemblance to the macroconidiophore bearing suppressed macroconidia, such as often occurs in old cultures: and in the absence of any spores, the identification of the perithecia must be doubtful. In any case the evidence scarcely supports the conclusions formed by Massee.

Prillieux and Delacroix.

Prillieux and Delacroix (7) investigated (in France) specimens of sugar cane from Mauritius attacked by a disease which they attributed to *Coniothyrium melasporum* (Berk.) Sacc. They considered that the fungus was identical with Massee's *Melanconium*, and with a species said to occur on sugar cane in Australia, which Berkeley named *Darluca melaspora;* Thiselton-Dyer has, however, stated that Berkeley's fungus came from Porto Rico, and is a *Diplodia;* so that the latter part of their identification is incorrect.

In addition to *Coniothyrium*, they obtained from the decayed canes an "endocellular" form of conidium, supposed to be identical with the macroconidia of Massee's paper. The conidia were produced in chains of five to ten at the ends of the hyphæ within the decaying tissues; they were black, oval, somewhat truncate, sometimes pyriform, or barrel-shaped, 18 × 9 μ. Intercalary or terminal chlamydospores, about 15 μ diameter, were also observed. On placing diseased canes in damp chambers, the cut surfaces were covered with a black velvety coating formed by chains of the same conidia. When sown in nutrient media, these spores, which the authors here style brown, produced a white mycelium which practically remained sterile; only occasionally were found chains of

hyaline conidia, $10 \times 6\text{–}7\ \mu$, which the authors believe were identical with Massee's microconidia.

It is to be noted that the conidia observed by Prillieux and Delacroix are styled "endocellular," because they were formed within the decaying cane; the term must not be confused with "endoconidia," which has been applied to the spores of *Thielaviopsis*, because they are formed within the hypha. Neither in the figures nor the text is there any indication that Prillieux and Delacroix saw conidia produced within the hyphæ; and the absence of any reference to this, the most striking feature of *Thielaviopsis*, casts some doubt upon their determination of their species. They did not observe the characteristic odour in their cultures.

Thiselton-Dyer.

Howard's account of his investigations is prefaced by a short summary by Sir W. T. Thiselton-Dyer (9), in which the latter upholds Massee's view that *Thielaviopsis paradoxa* is genetically connected with *Trichosphæria sacchari*. He cites Massee's experiment in which macro- and micro-conidia of *Thielaviopsis* were produced in a flask culture started with *Melanconium* spores, and dismisses Went's suggestion, that the culture was impure, on the ground that the *Melanconium* spores are produced on the exterior of the cane, while the macroconidia of *Thielaviopsis* are produced only in the interior, so that a mixture of the two is improbable. In this respect, however, his information was incorrect, for the macroconidia are produced in abundance on the exterior. He also states that Howard obtained the macro- and micro-conidia without difficulty by inoculating the interior of healthy canes with *Melanconium* spores, and that Prillieux and Delacroix appear to have been equally successful. Howard, however, has since withdrawn his claim; and the reference to Prillieux and Delacroix is apparently based upon a misinterpretation of their account. The latter authors state (7) "En dehors de la forme *Coniothyrium*, le mycelium nous a montre une forme conidienne endocellulaire déjà observée par M. Massee. Les conidies se produisent a l'extremité des filaments mycéliens dans les tissus de la canne

à sucre, mais lorsque celle-ci est tuée depuis longtemps et que les contenus cellulaires ont entièrement disparu." It is evident from the context that "le mycelium" refers to the mixed mycelium in the naturally diseased sugar cane, and not to the mycelium produced by artificial infection; they did not succeed in reproducing the *Coniothyrium*, or any other form, in artificially infected cane, nor did the latter decay to any marked extent.

Howard.

Howard's investigations were carried out in Barbados, with the object of deciding the disputed life history of *Trichosphæria sacchari.* As the result of an extensive series of cultures, he stated (10) that all attempts to produce *Thielaviopsis* from *Melanconium* spores in sterilized media failed, but that he was able to secure the desired result by inoculating unsterilized pieces of sugar cane. In a later communication (11), however, he states that he was unable to repeat this success, and admits that the sugar cane used was probably previously infected. He was not able to find the perithecia of *Trichosphæria sacchari* on dead canes, nor to obtain it in his cultures. He concludes that the whole of the evidence obtained points to the *Melanconium* being quite distinct from *Thielaviopsis.*

Cultures of mixed macro- and micro-conidia of *Thielaviopsis* on sterilized cane slabs produced a white mycelium in twenty-four hours; they turned black in three days owing to the formation of large numbers of microconidia and a few macroconidia. The same result was obtained in plate and flask cultures.

The development of the spores was studied separately in hanging drops. The macroconidia "germinated in five hours after sowing, and in eleven hours the hypha commenced to branch. In eighteen hours the drop was filled with a branched septate colourless mycelium, which exhibited very rapid growth. In twenty-four hours some of the hyphæ commenced to grow down into the air, especially round the margin of the drop. This behaviour soon became general all over the drop. The aerial mycelium appeared olive in colour, and grew with great rapidity. One of these aerial hyphæ was

fixed, and stages of its development were obtained under a higher power. Three hours after leaving the drop the hypha commenced to bend, and the contents showed segmentation. Soon after this appearance the hypha became top-heavy and fell back on to the surface of the drop. This was the signal for the rapid liberation of a chain of grayish rectangular conidia, averaging $7 \times 10\ \mu$, from the distal end of the aerial hypha. This behaviour of the aerial hyphæ was found to be general, and, except round the edges, the surface of the drop was speedily covered with ejected spores. The aerial hyphæ proved to be microconidiophores and the spores microconidia. When first extruded from the hyphæ the conidia are grayish in colour, rectangular in shape, and filled with granular protoplasm. In an hour after extrusion from the conidiophore the protoplasm of the conidium became vacuolated, and the conidia became rounder and larger. After this they gradually turned brown, and in twenty-four hours became reddish-brown, with a darker coloured central portion, and measured 15 to $10\ \mu \times 9$ to $7\ \mu$. The conidiophores measured $300\ \mu$ or more in length.

"During the above developments the submerged hyphæ were observed to form short branches, from which chains of conidia, larger and darker in colour than the microconidia, were produced. Several likely portions of mycelium were fixed, and stages in the formation of these, which proved to be macroconidia, were observed. The short clavate hyphæ soon showed the formation of a clear band near the apex, which divided off the protoplasm of the globose end from the remainder. Five minutes later the cell wall at the apex of the hypha disappeared, and a spherical mass of granular protoplasm was extruded. A distinct cell wall was evident forty minutes after, and the protoplasm was now more coarsely granular and showed vacuolation. After this more conidia were formed in basipetal succession in a chain. Their protoplasm became vacuolated, and the walls gradually darkened. When first extruded the protoplasm is finely granular, about thirty minutes afterwards several small vacuoles appear, which gradually approach the centre and coalesce. After the formation of the central vacuole the wall begins to darken, and in

twelve hours becomes sooty black in colour, when the central vacuole can no longer be observed. They measure on the average 22 × 15 μ.

"In many cases in this drop submerged macroconidiophores and collapsed aerial microconidiophores were seen to be developed from the same hypha, thus bearing out Massee's statement that micro- and macro-conidia are developed from the same mycelium. The drop in question was freely exposed to the diffused light of the laboratory, but not to direct sunlight, consequently darkness is not necessary for the formation of macroconidia. A similar development was observed in several other hanging drops containing macroconidia only.

"A hanging-drop culture was obtained containing a single microconidium. The spore germinated six hours after sowing and sent out a colourless septate hypha which soon branched. The mycelium quickly extended right through the drop, and its subsequent development was similar in all respects to that described above in the case of the macroconidia. Aerial microconidiophores were formed as before, which ejected chains of microconidia, while the submerged hyphæ formed chains of macroconidia inside the drop.

"The number of microconidia formed by one conidiophore is frequently very large, as many as ninety being observed.

"The development of the micro- and macro-conidia is therefore practically identical; had the drops not been labelled it would have been impossible to have distinguished between them."

Howard states that he separated the macro- and microconidia by beating up the mycelium in water and pouring off the upper portion. "The macroconidia being larger and heavier, subsided more quickly than the lighter microconidia, and therefore the lower layers of water were richer in the former bodies."

F. von Höhnel.

Sporochisma paradoxum was rediscovered, on the endosperm of a coconut in Vienna, by Dr. F. v. Höhnel (12). He considered that it was identical with *Thielaviopsis ethaceticus* Went, and submitted specimens to Went, who confirmed his

opinion. The mycelium was hyaline or slightly brownish, 3–5 μ thick, and not much branched, the branches being almost at right angles to the main hyphæ. The conidiferous hyphæ were perpendicular to the substratum, pale brown, usually simple and scattered, up to more than 200 μ long; they were 8–12 μ in diameter below and 4–5 μ above, and furnished with one to three cross walls towards the base. The apices of the conidiferous hyphæ were without exception open, and the spores were formed within the hyphæ. In some cases these erect hyphæ were massed together into cushions on a foundation of interwoven hyphæ. (This is the only record of any form resembling de Seynes "*Stysanus*" form. It is curious that it should only have been observed in "wild" growths in temperate climates, prior to recent observations in Ceylon.)

The spores were either thin-walled, hyaline, shortly cylindric, 10 × 5 μ (*i.e.*, microconidia), or elliptical, black-brown, almost opaque, thick-walled, 10–18 × 7–10½ μ, generally 12 × 8–9 μ (*i.e.*, macroconidia). All intermediate stages between these two extremes occurred. According to von Höhnel, the dark spore can develop from the hyaline. In some cases the whole chain of spores was hyaline; in others it was partly hyaline and partly dark, while black spores were sometimes found within the hypha. He states that the hyaline spores are not a separate form, but only a stage in the development of the dark spores; and refers to the general occurrence of hyaline spores in other dark-spored conidial species. The fully developed spores are, according to his view, brown. He declares that Went's statement that the macroconidia are formed in a different way from the microconidia is an error, but it is clear that he did not see the macroconidiophores, and hence could not distinguish between the two kinds of conidia.

Cobb.

Cobb examined *Thielaviopsis paradoxa* in connection with sugar cane (14) and pineapple (15) diseases in Hawaii. He states that the mycelium, at first colourless, becomes at last light or dark brown, though never the latter colour except in the fully decomposed tissues of the heart of the cane; it varied in thickness from 3 to 8 μ.

The microconidiophores were about 100 μ long and of varying diameter according to the part measured, being widest (8–10 μ) considerably behind the middle, and thence tapering to the open end. His figures represent them as terminal, not lateral. The microconidia were produced within the hypha, and were cylindrical, nearly colourless, 10–14 × 5 μ, in numbers up to twenty, but generally less than ten. Sometimes they were smaller, ellipsoidal, with a thicker and darker wall.

The macroconidia are said to be borne in an entirely different manner, in chains at the ends of special branches. They were more or less ellipsoidal, brown or blackish, and measured 16–19 × 10–12 μ.

Cobb states that the microconidia germinate readily, merely in the presence of moisture, but that the macroconidia require a period of rest before germination. The latter observation is incorrect. Contrary to the case of coconut, and the experience of the workers with sugar cane, Cobb states that both micro- and macro-conidia are formed within the tissues of the pineapple.

He describes (15) another form of microconidium which occurred on the cut surface of diseased pineapple shortly after cutting. These were formed in the usual way, within the tube, but were united in moniliform chains as "in the case of the aerial conidia of *Sphærotheca pannosa* and other *Erisyphaceæ*." His figure resembles a chain of conidia of *Cystopus*. (Nothing of this kind has been observed by other investigators; the conidia first formed on the cut surface of diseased tissues are normal microconidia, which may adhere in chains but are united.)

In the germination of the microconidia, the spore is said to become nearly spherical.

Lewton Brain.

Lewton Brain (16) working in Hawaii claims to have obtained *Thielaviopsis* spores by sowing *Melanconium* spores in culture media. He writes: "The evidence for the view that *Thielaviopsis* and *Melanconium* are different stages of one and the same figure is, briefly, that when we sow *Melanconium*

spores under certain conditions in culture media, the mycelium which arises produces spores which are identical in form and size and method of formation with the spores of *Thielaviopsis* ; other observers have found this, and I have also secured the same results. On making a few hurried trials for the purposes of this lecture, I was unable to repeat my previous results." This was written in 1907, but no further particulars have been published.

Butler.

Butler (13) cultivated *Thielaviopsis paradoxa* during the course of investigations into the diseases of sugar cane in India. He writes : "Two different kinds of spores are produced, and the blackening which eventually is seen in the pith is due to one of these.

"The first spore form—the macroconidia—is formed within the tissues. The spores are produced in chains extruded from the tips of short lateral filaments, and are olive-green and thick-walled. I have never seen macroconidia budded off basipetally as described by Went.

"The second spore form—the microconidia—is formed on special lateral branches in chains like the first, developed within the filament (which is often like a miniature cannon), and expelled through an opening at its tip. The spores are formed usually at the surface ....

"It has been stated that this fungus, like *Colletotrichum falcatum*, is only a form of *Trichosphæria sacchari*. I have kept pure cultures on cane slabs, starting from a single micro-conidium, under observation for more than a year, without obtaining anything but the macro- and micro-conidia. In the opposite direction, out of many dozens of cultures of *Colletotrichum falcatum* in the last two years I have never obtained macro- or micro-conidia. This is in accordance with the view now held in Java that both are independent species."

South.

The question of the connection between *Trichosphæria sacchari* and *Thielaviopsis paradoxa* has recently been discussed by F. W. South (17) who favours the view that the former

has an endoconidial stage, though it is doubtful whether that stage is identical with *Thielaviopsis*. His account contains several misquotations. He writes: "Massee states that an endospore condition consisting of macro- and micro-conidia very frequently developed in pure cultures of the *Melanconium* fungus in the Laboratory at Kew. Prillieux and Delacroix confirm this, and more recently Lewton Brain has also obtained them in Hawaii." Massee, however, only records one instance of this in flask cultures, and none in hanging drops; on the same evidence it would be possible, from Ceylon experience, to claim that *Pestalozzia palmarum* was a stage of *Thielaviopsis*. Further, Prillieux and Delacroix did not confirm Massee's culture results; they merely found the *Melanconium* and endoconidia together in diseased cane; and no account of Lewton Brain's experiments has yet been published.

He further states that subsequent cultures from single spores have disproved Went's suggestion that Massee's culture was impure; but here again this apparently rests upon unpublished work, and cannot be accepted without some particulars. Another statement is to the effect that Butler suggests that the endoconidia of *Sphæronema adiposum* may be identical with *Thielaviopsis*, but no such suggestion appears in Butler's paper.

Four arguments are put forward in favour of the view that the two fungi are genetically connected. The last three of these prove nothing; and the first is misleading, since it states that *Trichosphæria sacchari* forms endoconidia in cultures. As a matter of fact, nothing was obtained from the spores of *Trichosphæria sacchari*; *Thielaviopsis* is claimed to have been produced from *Melanconium* spores, but there is no proof that the *Melanconium* is a stage of the *Trichosphæria*. There is another error in the third argument: Stockdale (West Indian Bulletin, VIII., p. 163) did not find *Trichosphæria* on pineapples; Howard found *Thielaviopsis*, but Stockdale records it under Massee's name, as he apparently accepts Massee's proof that the two are forms of the same fungus.

The arguments quoted in opposition to Massee's view are equally weak, and there is an error in the statement that

Trichosphæria sacchari is found in Java. It may be as well to restate the fact that the *Trichosphæria* has only been found once; two perithecia were found at Kew on diseased sugar cane from the West Indies. Howard failed to find it in Barbados, and Went does not record it from Java. Butler states that he found the *Melanconium* stage of *Trichosphæria sacchari* twice in India, but he is assuming the unproved connection between the two forms.

The real argument in opposition is that no one has succeeded in proving any connection between *Trichosphæria sacchari*, the *Melanconium*, and *Thielaviopsis paradoxa* by experiments which are not open to obvious and fatal objections.

Most of the errors noted above are due to the fact that all the supposed stages of *Trichosphæria sacchari* are referred to indiscriminately under that name. In leading evidence in support of their connection, it is surely necessary to distinguish the forms which the different recorders were referring to.

II.—OBSERVATIONS IN CEYLON.

The Mycelium.

Though *Thielaviopsis paradoxa* was originally described as having two kinds of spores, the one hyaline and the other coloured, all its spores are, ultimately, coloured: and with few exceptions they are oval when mature. When sown in water, the mature spores do not germinate, but in nutrient media they begin to germinate in about five hours. Various nutrient solutions have been tried, but the best in this case is made by boiling sugar cane in tap water; the solution was usually concentrated until it contained about 6 per cent. cane sugar, but this is not necessarily an optimum for *Thielaviopsis*. The spores were sown in hanging drops, flasks, and cane-extract-agar plates, as well as on blocks of sugar cane and the stem tissues of the coconut.

When the spore begins to germinate, the dark, thick outer wall splits longitudinally—sometimes, in oval spores, from pole to pole—and the "germ tube" gradually pushes out through the crack, usually about the middle of the spore.

The spores do not become spherical, as stated by Cobb (14). The "germ tube" generally takes a tongue-shaped form, its base occupying about one-half the length of the spore, but in some cases it is semicircular with a base occupying the whole length of the spore. After this has protruded for about 20–40 μ, the apex proceeds to grow on as a normal hypha, which is soon cut off by a septum from the tongue. Sometimes two hyphæ are produced from the thickened germ tube.

The mycelium is strikingly regular, and usually stout, 6-8 μ in diameter. I have measured mycelium 12 μ in diameter on sugar agar. In poor growths it may be only 3–4 μ in diameter; I have noticed this from spores which had been kept dry for several weeks, but the slender mycelium produced thicker hyphæ shortly afterwards. It branches at an acute angle, the branches following the same general direction as the main hypha. At first it is filled with fine-grained protoplasm, but it becomes strongly vacuolate later, and contains scattered, refringent granules when old. The distance between the septa varies from 40 to 200 μ in the main hyphæ, but about 80 μ is a common distance. The mycelium is at first hyaline, and becomes fuliginous when old. In hanging drops and flask cultures, this change is not well marked; the germ tube is usually strongly coloured, but the remainder of the mycelium is almost hyaline. On solid media, *e.g.*, coconut and sugar cane, the mycelium generally becomes fairly dark; but on agar plates made with a decoction of coconut stem, and therefore poor in sugar, the mycelium remained white in mass during the fourteen days for which it was kept.

After about twelve hours from the time of sowing the spores the formation of microconidia begins. In flask cultures the surface is usually covered with white mycelium and microconidiophores at the end of twenty-four hours. The second form of spore—the macroconidium—then appears, and the culture gradually becomes greenish-black and finally quite black. The final change generally occurs in two days, sometimes in three, from sowing; it is due in part to a slight darkening of the mycelium, but chiefly to the enormous numbers of dark spores produced.

The Microconidia.

The microconidiophores arise as stout, lateral branches practically perpendicular to the vegetative hyphæ. The branch usually springs from a narrow base, and almost immediately swells out to a diameter greater than that of the parent hypha. It grows on for from 30 to 100 μ, increasing slightly in diameter upwards until it attains 7 or 12 μ; for the remainder of its growth it tapers uniformly, until it reaches a length of from 90 to over 300 μ and an apical diameter of 4–6 μ. The conidiophore is cut off from the main hypha by a septum shortly above the point of origin. If it is a short conidiophore (about 90 μ long), this is the only septum in it. But the longer conidiophores have usually two or three additional cross septa, the highest being about 80 μ from the base, a little below the point at which the conidiophore begins to taper. The normal conidiophore, therefore, consists of a sterile basal portion, which is one to three septate, surmounted by a long tapering tube. All the septa are formed before the spores are produced. The sterile base is often curved, but the long tapering upper cell is always straight. The growth of the conidiophores is fairly rapid. In one case an extension of 20 μ occurred in 23 minutes; in another instance 70 μ in 105 minutes.

It is not easy to observe the development of the microconidia in hanging drops owing to the length of the microconidiophore, though occasionally one may lie parallel to the cover glass. The majority, however, project from the drop into the cell below. I have obtained better results by sowing the spores in drops of a sugar solution placed on sterilized slides and covered by a large (1 inch square) cover glass supported on four wax feet. By pressing down the cover glass, a film of liquid of any desired thickness can be obtained, and the conidiophores must develop horizontally, or nearly so. Development, probably through lack of oxygen, is retarded by this method; but this is an advantage since it delays the appearance of the conidiophores until the next day. When the cultures are examined, the liquid may be prevented from evaporating by placing strips of moist blotting paper round the cover glass. Cultures made in this way remain pure for four or five days, being kept, of course, between the

examinations, in a damp chamber. I have been able to keep them under the microscope for three hours continuously by occasionally moistening the blotting paper.

When mature, the conidiophore is hyaline or grayish, and is filled with finely granular protoplasm. It remains quiescent for some time after it has reached its full extension, and then begins to extrude spores from the apex. A cell wall is developed round the protoplasm in the apex of the tube ; at a distance of about 10 μ behind the tip, the protoplasm becomes slightly constricted, as is evident from the minute V-shaped depression which is visible on each side within the tube in optical section ; a cross septum next appears as a dark line at this level, and the terminal mass of protoplasm thus completes its cell wall ; the apex of the tube is then dissolved, and the spore is slowly extruded by the expansion of the protoplasm behind it. The apex of the conidiophore as a rule is not inflated ; sometimes it is slightly swollen, and then the spore first extruded is somewhat capitate, but the swelling in the most pronounced cases is only slight. In general, the microconidia, when first extruded, are almost exactly rectangular in outline.

By the time the proximal end of the first conidium has reached the apex of the tube, another septum appears in the tube at the same distance from the apex as before, thus completing a second spore, which follows the first out of the tube without any resting period ; and this process is continued until as many as eighty spores have been extruded. The spores issue in a steady continuous stream, each pressing close on the previous one. It is evident that when the cross septum appears in the tube, two terminal spore walls are formed, one of which completes the spore wall of the upper spore while the other begins the wall of the lower. At first, during the extrusion of the first twenty or thirty spores, the cross septum appears always at the same distance from the apex : there is therefore never more than one spore within the tube, and that is just about to be extruded. In the later stages, however, the formation of spores is more rapid than the process of extrusion, and it is possible to find two or three completed spores within the tube in addition to the one which is being pushed out. In the final stages, the process appears

to vary ; normally, the remaining protoplasm becomes highly vacuolated and may therefore push out the last spore. I have however seen a spore separate from the protoplasm (which was still dense and granular) and advance towards the open end, leaving a gap of about 10 μ ; the protoplasm then advanced and diminished the gap to about 5 μ, after which the spore moved forward again ; in this case the residual protoplasm did not possess a terminal wall. It seems probable that the extrusion of the last-formed spores may be in part a capillarity effect. It is not, however, uncommon to find one or more spores left permanently in the tube.

The time of extrusion of the earlier conidia occupies from three to six minutes. In one instance, the fifth was extruded in four minutes, and the sixth in six minutes. In another case, the nineteenth was extruded in five minutes thirty-five seconds, the twentieth in five minutes five seconds, and the twenty-first in six minutes twenty seconds.

When the conidia are extruded, they adhere by their ends in a chain. If the conidiophore projects from the surface of a liquid or solid medium. the chain soon falls over and the conidia come to lie in a mass beneath the apex of the conidiophore. When the conidiophore lies in a film of water on a cover glass, the first three or four conidia are pushed out in a straight line along the glass ; the force required to push them further is evidently greater than the cohesion of the spores can withstand, for the chain is then bent and the succeeding conidia are pushed up by the side of the former, so that they come to be arranged at first in more or less parallel lines and later in an irregular group ; in these cases, when a conidium has to overcome the pressure of the mass of spores in front of it, the final stage of its extrusion occurs with a distinct jerk. When the conidiophore lies within a hanging drop, the spores remain in contact and form a long chain containing up to eighty or more. Frequently the chain assumes a zigzag pattern as it is pushed forward. The shapes assumed are exactly those obtained by placing dominoes end to end in one line and pushing them across a table.

The extrusion of the microconidia, as seen in Ceylon, is a steady continuous process. It is probable that the times

given above are greater than would be the case under natural conditions, but it is scarcely likely that the process would be materially different. It is, however, very different from Howard's account (10). Howard states: "Three hours after leaving the drop, the hypha (*i.e.*, conidiophore) commenced to bend, and the contents showed segmentation. Soon after this appearance the hypha became top heavy and fell back on to the surface of the drop. This was the signal for the rapid liberation of a chain of grayish rectangular conidia." It may be pointed out that if the conidiophore were bent abruptly, liberation of previously-formed conidia would be impossible, except for those on the distal side of the bend. Further, if all the contents were segmented into spore equivalents, there would not be room, even in the longest conidiophore, for more than twenty spores; yet we know that it may produce eighty or more, and that even after it has produced forty, the tube is still nearly filled with protoplasm which does not show segmentation. It is not possible, therefore, that the conidiophore should contain a number of preformed conidia, awaiting a favourable moment for rapid liberation. The only other observation on the extrusion of the microconidia is that of Massee, who states that they are produced in the same way as the macroconidia; the modes of production of the two kinds of spores differ, however, in several particulars.

I have stated above that the apex of the conidiophore is dissolved. This, however, is a matter of conjecture. It certainly does not split off a cap or lid, and there are no indications of any rupture. The end of the tube is quite even, and it generally fits quite closely round the escaping conidia; it terminates as evenly and regularly as a gun-barrel. Sometimes, however, especially in old specimens, the edge is recurved; but even in these cases the bore of the tube is not widened, and the recurved portion is not more than 1 μ broad. I have never seen a trumpet-shaped mouth, as figured by Massee (6). As a rule, the end of the tube can only be detected when the conidia are escaping, by noting the apparent change in thickness of the wall of the escaping spore.

If undisturbed, the microconidia remain in chains in the liquid. But they are merely in contact, end to end, and

are not organically connected. I have on several occasions noted the appearance figured by Cobb (see p. 523), but have always been able to determine that the spores were not united.

When first extruded, the microconidia are hyaline, and almost exactly rectangular in outline. Their length is usually 8–12 μ, but I have measured one 32 μ long in a chain in which none of the remainder exceeded 12 μ. Their breadth depends upon the apical diameter of the conidiophore : usually it is 5 μ, but sometimes only 4 μ, and rarely 6 μ. Subsequently they become oval, and gradually darken until they are fuliginous, or greenish black, but this change in colour is much slower than in the case of the macroconidia. In hanging drops, the macroconidia have usually been produced and have changed colour before the change of the microconidia has occurred. The spores which remain permanently within the conidiophore darken much more rapidly than those which have been extruded. Also, if the hyaline microconidia are transferred to a hanging drop of water, the colour change is still further delayed : in one such instance, only fifty per cent. of the spores changed colour in fourteen days. It would appear from this that the colour change is dependent upon some product of the mycelium. No hyaline conidia are to be found in a flask culture six days old.

When the hyaline conidia are sown in a hanging drop of water, some of them put out a germ tube, usually from one corner, but this seldom grows longer than 5 to 10 μ. If sown in sugar cane extract, the subsequent development is exactly the same as in the case of the mature conidia.

When fully mature the microconidia are greenish-black or brownish-black, oval, usually 11–14 × 7–9 μ ; some are larger than this ; and sometimes the smallest become spherical, 5–7 μ diameter.

The Macroconidia.

About twenty-four hours from the time of sowing the spores, the macroconidia begin to appear. At first the macroconidiophores are produced with the last of the microconidiophores, and on the same hyphæ, but later all the conidiophores produced are macroconidiophores. They are short, lateral

branches, perpendicular to the main hypha, 20–80 μ long and 4 μ in diameter. Like the microconidiophores, they are cut off by a septum just above the point of origin, and the longer of them may have one or two additional septa, rather close together, above this. At first they are slightly clavate and filled with finely granular protoplasm.

When the conidiophore is mature, the apex dissolves, and some of the protoplasm is extruded. In general the extruded mass assumes an oval shape, but sometimes it becomes spherical. A wall is then formed round it, with a flat septum, cutting it off from the remaining protoplasm, at the apex of the conidiophore. At first the contents of the spore are finely granular, but they soon become vacuolated, and the spore increases in size. Meanwhile another portion of the protoplasm within the conidiophore is seen to divide off, and is gradually pushed out: as it emerges it is more or less pyriform, but when completely extruded it becomes oval and proceeds to form a cell wall, &c., exactly in the manner of the first. I have never been able to detect any division of the protoplasm before the extrusion of the first spore mass, but all succeeding spore masses are clearly cut off, one at a time, within the tube. This process is continued until a chain of spores, usually about a dozen, is produced. The conidiophore is then highly vacuolated, and subsequently appears empty. The spores are generally united, end to end, but sometimes a chain is divided into two or three separate portions. The spores increase in size after their formation, but the terminal one is always the largest. Short conidiophores, which form only one conidium, are not uncommon, and any number from this to twenty may be produced.

The production of macroconidia is a much slower process than that of the microconidia. On the average, one microconidium is extruded in from forty-five to sixty minutes. They begin to darken about three hours after extrusion; the chain of macroconidia therefore exhibits dark spores at the apex and hyaline spores at the base during the period of formation. At first the spores decrease in size from the apex to the base of the chain, but subsequently all but the apical spore attain practically the same dimensions.

The dimensions of the macroconidia vary enormously. $17 \times 10\ \mu$ is a common size, and so is $12 \times 8\ \mu$. But many are only $8 \times 5\ \mu$, or $9 \times 7\ \mu$; while, on the other hand, some attain $19–30 \times 11–18\ \mu$. When mature, they are greenish-black or brownish-black. In general, they are oval, truncate when they remain united; but sometimes they are pyriform, and the apical spore may be spherical. Howard states (10) that the colour is contained in the cell contents, not in the wall; but it is evident when they germinate that the wall is coloured and the contents hyaline.

There is no doubt that the macroconidia are formed by the extrusion of masses of protoplasm. When the chain of conidia is fully formed, it frequently remains in contact with the apex of the conidiophore, and as the latter is then practically not inflated at the top, the conidia appear to be ordinary acrogenous conidia. But if the process of formation is watched, their production from within the conidiophore is unmistakable. Sometimes the last-formed conidium of a chain fails to be pushed completely out of the tube; in that case, the extruded portion becomes oval, while the part still in the tube remains cylindric, and the conidium acquires its spore wall and blackens while retaining this shape. The occurrence of such spores, socketed in the tube, confirms the previous observations as to the mode of production.

Massee has stated (6) that by staining with chlor-zinc-iodide he was able to determine that the wall of the developing spore first began to be formed at the distal end, and thinned away along the sides. I have not been able to stain the wall with this re-agent.

The macroconidia do not germinate in water. When sown in a nutrient solution they germinate in about five hours. Cobb's statement that they require a period of rest before germination is not correct.

In flask cultures, the conidia ultimately form a black powdery mass on the surface of the liquid.

As Howard (10) has previously shown, it is not necessary for the formation of macroconidia that the cultures should be kept in the dark.

The Colour of the Spores.

The differences in the recorded colours of the spores, as described by different observers, are at first somewhat bewildering. de Seynes states that the microconidia are hyaline, and the macroconidia olivaceous brown, black in mass ; but he notes that some of the microconidia assume the colour of the macroconidia. Went (8) gives the microconidia as colourless, sometimes slightly coloured, and the macroconidia as dark olive-green. According to Massee (6) the microconidia are pale reddish-brown, while the macroconidia are clear olive-green, then sooty-brown, and finally opaque blackish brown. Prillieux and Delacroix (7) state that the microconidia are hyaline and the macroconidia black. Howard (10) states that the microconidia are hyaline, then reddish-brown, and the macroconidia sooty black. V. Höhnel (12) regards the supposed two forms as identical, the final colour being brown. Cobb (14) states that the microconidia are nearly colourless, sometimes darker, and the macroconidia brown or blackish.

With one possible exception, all these colours are correct at some stage or other. The microconidia are at first hyaline, then fuliginous, then almost black, while the macroconidia are hyaline, then clear green or olive-green, then greenish-black. They are black in mass. If they are left lying in the culture medium, or if they are dried, or preserved in alcohol, or mounted in glycerine, they become blackish-brown. I have never been able to detect any pronounced reddish tint.

Similar cases are not uncommon among the *Phæosporæ*. The extruded spores of *Botryodiplodia theobromæ*, for example, are hyaline when the substratum is dry, and they remain hyaline for a long period ; sent to Europe from America in this condition, the fungus was re-named *Macrophoma vestita*. In fresh pycnidia of the same species, the spores may be grayish, or greenish-black, or violet-black. But old spores, whether preserved dry or in alcohol, are blackish-brown, black in mass.

The Order of Occurrence.

The spores which are formed within the decaying tissues of sugar cane or coconut are apparently always macroconidia. If the diseased tissue is cut and kept damp, microconidiophores

appear on hyaline mycelium on the cut surface. Hence the macroconidia have been styled the first kind of spore and the microconidia a higher type more adapted to aerial conditions.

But if the spores are sown in nutrient solutions, or on agar plates, or on blocks of sugar cane, &c., the microconidia invariably appear first. If the substratum is somewhat dry, the microconidial stage may be of short duration, but it is never absent. Hence the microconidium must be regarded as the first type of spore.

Several observers have considered that the macroconidia were produced only within the tissue of the host plant, or beneath the surface of solid or liquid media. in contrast to the microconidia, which are supposed to be always aerial. This view, however, is not correct. It is true that in hanging drops the majority of the microconidiophores project into the air, while the chains of macroconidia do not; but this is merely owing to the greater length of the microconidiophore. On decayed tissue, the crop of aerial microconidiophores is always followed by the production of aerial macroconidiophores, and the same occurs also in flask cultures and on agar plates. When the fungus is grown in films of nutrient solution as described on p. 528, most of the conidiophores, both micro and macro, are produced at the edge of the film. but *both kinds* are also produced within the film. There is therefore no such delimitation as has been supposed.

One variation from the normal course occurred on agar plates made with a decoction of coconut stem tissue. Two sets of plates were inoculated, the one with hyaline microconidia and the other with black spores. Both series grew well, and in three days the plates were covered with a white mass of mycelium bearing microconidiophores. On the fourth day, de Seynes' *Stysanus*-like fructification, which consists entirely of microconidiophores, appeared, and this continued to be produced for the next four days. After the expiration of fourteen days the plates were still white, and there were no macroconidia. In this instance the macroconidial stage was eliminated. As there was no difference between the two series, this effect cannot be attributed to the type of spore employed in inoculation.

de Seynes' Stysanus-*like Fructification.*

The groups of conidiophores seen by de Seynes (3) and likened by him to the conidiophores of a *Stysanus* have not been recorded by any subsequent writer, though they are of quite common occurrence. On natural substrata, *e.g.*, diseased coconut and sugar cane, they occur when the cultivation is old, that is, after the micro- and macro-conidia have been produced, and the substratum is becoming rather dry. Similarly, they frequently occur on sugar-agar plates, when the culture is old and drying. An almost certain way of obtaining them is as follows: a drop of sugar cane extract placed on a sterilized glass slip is inoculated with *Thielaviopsis* spores and kept in a damp chamber; after a few days (two or three) the mycelium, which is now producing micro- and macro-conidia in abundance, runs from the drop over the slide in more or less radiating strands; the *Stysanus*-like fructification is then produced along these strands.

The foundation of these fructification is formed by a small plate of interwoven hyphæ, or by a number of hyphæ running parallel and close together, so as to form a strand. From a point on such a strand, or from the plate of hyphæ, a number of microconidiophores arise side by side and adhere to one another, thus forming an erect stalk from 1 to 3 mm. high and from 0·08 to 0·25 mm. in diameter. These extrude conidia in the usual way, but the conidia remain in a globule at the top of the "stalk." The stalk rapidly turns black, but the mass of conidia remains white much longer than the microconidia do in hanging drops; eventually, however, the mass darkens. The whole structure, pseudo-stalk and globose head of spores, superficially resembles a *Stilbum*, or a ripe *Sphæronema*; I have referred to it elsewhere as the "Sphæronemoid" stage, before I was aware that it had been noted by de Seynes. On sowing the spores in sugar cane extract, their identity with the normally-produced microconidia is fully established.

This form is produced if the spores are placed on pieces of filter paper, which are floated on the surface of a nutrient solution. From this and the other instances given above it would appear that it is some way dependent upon the water supply, being produced when this is diminishing or not readily

available. It is interesting to note that when the spores of *Thielaviopsis* are sown in nutrient solutions which contain poisons in a concentration approaching that which inhibits their germination, the *Stysanus*-like form is frequently produced; small floating islands of mycelium appear, and these, after bearing a few micro- and macro-conidia in the usual way, produce the upright fructifications.

The most puzzling feature about these compound fructifications is the fact that they are composed of microconidiophores. Under normal conditions the microconidiophores are the *first* form produced by *Thielaviopsis*, and they are soon succeeded by the macroconidiophores. But, in the *Stysanus*-like fructification, there is a return to microconidiophores when the conditions of growth are unfavourable. This would appear to negative any supposition that the production of the two kinds of conidiophore is dependent upon the available supply of food.

Nothing has been observed which would throw any light on the cause of the change from the production of microconidiophores to the production of macroconidiophores. The macroconidiophore appears to be a depauperate form of the microconidiophore, but the return to microconidiophores, when the culture is old or when the conditions are unfavourable, would seem to render inadequate any explanation based on food supply or substances excreted by the fungus during its growth.

Variation in the Macroconidiophore.

In old hanging-drop cultures, the macroconidiophore frequently fails to open. The upper part of the conidiophore usually becomes curved, either in simple hook fashion or in a complete coil, and its contents round off into one large oval spore mass or segment into a chain of two or three. These spore masses then acquire a spore wall and turn black, while still retained within the conidiophore. They are arrested macroconidia, and can only be liberated by the decay of the conidiophore. It seems probable that de Seynes' macroconidia—which occurred singly or in chains of two or three, were segmented off from the parent cell within the hypha, and

were set free by the destruction of the upper part of the wall of the parent cell—may have been only arrested macroconidia as described above.

A similar development occurred in flask cultures, to which 0·2 and 0·3 per cent. of hydrochloric acid and 0·09 and 0·1 per cent. of sulphuric acid, respectively, had been added. The mycelium developed in the form of rather compact submerged spheres, which turned pale brown at their surfaces. These spheres bore large numbers of suppressed macroconidia, but no other spores. In general, the conidiophores were not curved, and each bore one conidium only, but instances of two or three in a chain within the conidiophore were found.

Micro- v. Macro-conidia.

The separation of the two forms of conidia on the basis of size is to some extent misleading. I have measured microconidia, 17 and 32 μ in length, though they rarely approach the latter size. On the other hand, macroconidia, 8 × 5 μ or 9 × 7 μ, are not uncommon; and these are smaller than the average microconidium (11–14 × 7–9 μ). Howard's method of separating the two kinds of spores—by beating up the mycelium in water and allowing it to subside, whereby he supposed the upper layers contained chiefly microconidia—must therefore be regarded as fallacious. When the spores are recently formed but have changed colour, it is possible to identify the macroconidia by their more oval shape, their more vacuolate contents, and by the fact that they are sometimes *united* in chains; but many doubtful cases occur, and all these criteria fail when the spores are old and blackish-brown.

Practically, the only constant difference lies in the mode of formation of the spores and the structure of the conidiophores. The microconidiophore is the longer, and terminates in a long tapering tube, while the macroconidiophore is a short branch, of almost uniform diameter when empty; the former produces a large number of spores, up to eighty or more, while the latter produces twenty at most, and sometimes only one. The microconidium acquires its wall within the tube, and hence is cylindrical when extruded, but the wall of the macroconidium

is formed after the extrusion of its protoplasm, and hence it is oval from the beginning.

There is no difference between cultures established from macro- and micro-conidia respectively.

Other Stages of Thielaviopsis.

Though *Thielaviopsis* has been grown in flask cultures on sugar cane extract and artificial nutrient solutions, and the cultures have been kept in some cases for more than six months, no ascigerous or pycnidial stage has been observed. Similarly, nothing of the kind has been found in cultures on agar plates or on blocks of coconut or sugar cane tissue, nor has any other fungus been found in the field which could be united with *Thielaviopsis*.

Trichosphæria sacchari Mass., and the *Melanconium* so common in the West Indies, do not occur on coconut, and they have not yet been found on sugar cane in Ceylon. An ascigerous species, which has been named *Metasphæria cocoes*, occurred on coconut leaf stalks, but this is a common saprophyte on coconut, and its spores do not produce *Thielaviopsis* when sown in sugar cane extract. Two fungi are commonly found on coconut tissue attacked by *Thielaviopsis*, and they are frequently found in flask cultures if the latter have been inoculated with spores direct from the tissue: one of these is a *Chromosporium*, and the other *Pestalozzia palmarum* Cooke. Both these have been grown in pure culture, but they do not produce *Thielaviopsis*. *Sphæronema adiposum* Butler sometimes occurs on diseased coconut wood ; when the spores are sown in sugar cane extract, a mycelium which bears endoconidia is produced, but these endoconidia are clearly different from the endoconidia of *Thielaviopsis*.

The "Pineapple" Odour.

Sugar cane attacked by *Thielaviopsis* has, according to Went, a distinct odour of pineapples when cut open ; hence the disease of sugar cane caused by the fungus is known as the "Pineapple disease of sugar cane." According to Cobb, the odour is not always noticeable, and the strength varies with the variety of cane.

This odour is seldom noticeable when the stems of diseased coconut trees are cut open, though I have observed it on two or three occasions. If, however, the spores are sown on coconut stem tissue in a damp chamber, the odour is well marked on the second day ; on the third day the culture smells rather of apples ; and on the fourth and subsequent days no distinctive odour is perceptible. When *Thielaviopsis* is grown on sugar-agar, the smell similarly disappears in a few days, but it persists in flask cultures for a week or more.

According to Went (8), this odour is due to the production of ethyl acetate (ethyl acetic ester), and its disappearance is regarded as evidence that this substance is consumed by the fungus. The ethyl ester which has a pineapple odour is, however, according to Richter, ethyl butyric ester (Richter Ed. 6).

Growth on Coconut Tissue.

Experiments were made to determine to what extent *Thielaviopsis* would grow on the different tissues of the coconut. The pieces were not sterilized, but were cut from healthy tissues, trimmed with a sterilized knife, enclosed in sterilized dishes, and moistened with sterilized water.

(*a*) Pieces cut from a fresh green husk ; spores sown on the inner white tissue. No growth in two days. Poor growth, with macroconidia and the "*Stysanus*" form in five days.

(*b*) Brown husk from a stored nut, brown internally ; spores sown on inner brown tissue. No growth in fourteen days.

(*c*) Fresh green leaf stalk cut from the tree ; section cut near the base ; spores sown on the internal white tissue. No growth in two days. Very slight growth, with macroconidia, in five days.

(*d*) Leaf stalk taken immediately the leaf had fallen ; tissue brown internally, but not decayed and fibrous ; spores sown on internal brown tissue. No growth in fourteen days.

(*e*) Section of the bud through the developing leaves ; spores sown on the cut surface. No growth in seven days.

(*f*) Undifferentiated tissue from the bud ; spores sown on the cut surface. No growth in seven days. This piece developed two colonies of *Sterigmatocystis*, one colony of *Mucor stolonifer*, and seven colonies of *Pestalozzia palmarum*.

(*g*) White tissue from the centre of the stem. Good growth in two days, chiefly macroconidia, with a few microconidia.

This series of experiments shows that *Thielaviopsis* grows luxuriantly only on the stem tissues of the coconut. Its failure to develop on the immature bud tissues agrees with the observed fact that the disease, even on trees which have been hollowed out by it for several years, does not extend into the bud. Analyses by Mr. A. Bruce show that none of the tissues employed contain free sugars except the stem, and even there the amount is small. It would appear, therefore, that the growth of *Thielaviopsis* is governed by the amount of sugar available. If the tissue of the leaf stalk is boiled, sugar is obtained in abundance, probably from glucosides ; apparently, therefore, *Thielaviopsis* is not able to make use of this combined sugar.

The Need of Oxygen.

As the fungus grows and forms conidia within the tissues of the coconut and sugar cane, the effect of depriving it of oxygen was tried.

Two sterilized watch glasses were filled with sugar cane extract, and placed on glass supports under bell glasses standing in glass dishes. Spores from the same cultures were sown in each. A was isolated from the room atmosphere by a water seal, and the oxygen in B was absorbed with pyrogallic acid and caustic potash. There was a copious growth of *Thielaviopsis* in A after three days, but no growth in B at the end of a week. The spores and sugar solution from B were then transferred to a sterilized flask, where *Thielaviopsis* appeared and attained the macroconidial stage after one to two days.

Growth in Light and in Darkness.

In each of two 150 c. c. conical flasks, 50 c. c. of the same sugar cane extract was placed, and the flasks were inoculated

as far as possible with the same number of spores by suspending the latter in water and adding equal amounts to each. One of these was left on the laboratory table exposed to diffuse daylight, while the other was kept in complete darkness. After seven days the contents of both were filtered through tared filter papers, washed well with distilled water, and dried until the weight was constant. The dry weight of the culture grown in the dark was 0·270 grams; that of the culture grown in diffuse light was 0·143 grams.

The experiment was repeated, and the product dried and weighed after four days; the dry weight of the culture in the dark was 0·080 grams, while that of the culture in the light was 0·056 grams. There was no difference in the appearance of the two cultures; both in the light and in the dark they were black with macroconidia. It would appear, therefore, that *Thielaviopsis* grows more luxuriantly in darkness than in the light, and that the absence of light does not prevent the production of conidia.

The Longevity of the Spores.

The following experiment was instituted to determine how long the spores retained their germinative capacity under different conditions. The nutrient solution was poured away from a large flask culture, about ten days old, which contained an abundance of macroconidia. The mass of mycelium and spores was then shaken well with sterilized water, and the liquid with the suspended spores was poured through a filter. The process was repeated until a dozen filter papers uniformly covered with black spores had been obtained. These were then allowed to dry at the room temperature. Each filter paper was cut into four numbered pieces to secure uniformity as far as possible, and these were arranged in four lots as follows:—

A.—In a desiccator over calcium chloride in semi-darkness.

B.—In a closed and sealed glass vessel in semi-darkness.

C.—In a desiccator over calcium chloride exposed to full sunlight for four to six hours per day.

D.—In a closed and sealed glass vessel exposed with C.

In A the spores are quite dry and in semi-darkness ; in B they are merely air-dry, but under the same conditions of light. Similarly, C is quite dry, while D is only air-dry. C and D were placed in a window and were exposed to full sunlight every morning in December–January, from 7 A.M. to 1 P.M. In February–March the sun goes off the window earlier, and the vessels were therefore put outside each morning until 12 noon. The mornings were sunny throughout the sixteen weeks for which C and D were exposed, except on eleven occasions. The black bulb thermometer (*in vacuo*) exposed in the window by the side of C and D reached 50·5 at midday in January.

Samples were taken from each lot every seven days and placed in sterilized flasks of sugar cane extract. The results are given in the following table. The experiment was begun on November 14, and the first samples taken on November 21. The times given under A, B, C, D are those which elapsed before the formation of a good covering of macroconidia, not the time of germination, which is at least two days earlier :—

Sample taken.	A.	B.	C.	D.	Notes.
1908.	Days.	Days.	Days.	Days.	
Nov. 21 ..	3	3	3	4	—
Nov. 28 ..	3	3	4	—	D kept for fourteen days ; no growth.
Dec. 5 ..	3	3	—	—	C and D kept for fourteen days : no growth.
Dec. 12 ..	3	3	—	—	do.
Dec. 19 ..	3	3	4	—	D kept for fourteen days ; no growth.
Dec. 26 ..	3	3	—	—	C and D kept for fourteen days ; no growth.
1909.					
Jan. 2 ..	3	3	—	—	C and D kept for fourteen days : no growth.
Jan. 9 ..	3	3	6	—	D kept for fourteen days : no growth.
Jan. 16 ..	3	4	6	—	do.
Jan. 23 ..	3	3	4	—	do.

Sample taken.	A.	B.	C.	D.	Notes.
1909.	Days	Days.	Days.	Days.	
Jan. 30 ..	3	4	—	—	C and D kept for fourteen days; no growth.
Feb. 6 ..	3	4	—	—	do.
Feb. 13 ..	3	3	—	—	D discarded. C kept for fourteen days; no growth.
Feb. 20 ..	3	3	—	—	C kept for fourteen days; no growth.
Feb. 27 ..	4	4	—	—	do.
Mar. 6 ..	3	3	—	—	C discarded. March 13, 1909.
April 3 ..	3	3	—	—	—
Aug. 7 ..	4	5	—	—	—
Oct. 25 ..	4	—	—	—	B kept for twenty-two days.
Oct. 30 ..	4	—	—	—	Three samples from B.
Nov. 17 ..	3	—	—	—	B kept for twenty-five days.
Dec. 30 ..	4	—	—	—	B discarded.
1910.					
Jan. 8 ..	—	—	—	—	—
Jan. 17 ..	3	—	—	—	Growth fair.
Jan. 29 ..	—	—	—	—	No further growth.
Feb. 10 ..	—	—	—	—	do.
Feb. 19 ..	—	—	—	—	do.

Air-dry spores exposed to sunlight survived exposure for seven days, but were killed before the expiration of fourteen days; spores dried over calcium chloride and similarly exposed were in some cases killed within twenty-one days, but some survived for seventy days.

Air-dry spores in semi-darkness survived for two hundred and sixty-six days, but were dead at the end of three hundred and forty-five days. The experiment had unfortunately been neglected for nearly three months, under pressure of other work and through absence in field investigations. Spores dried over calcium chloride survived in some cases for four hundred and twenty-nine days, but none germinated after four hundred and forty-one days.

Lack of time has prevented further experiments to determine a closer limit for D, and to ascertain whether any spores survive if they are dried in full sunlight.

III.—EFFECT OF FUNGICIDES, &c., ON THE SPORES.

The following experiments sprang from an attempt to discover in how far the usual fungicides were effective in preventing the germination of the spores of *Thielaviopsis*. The first three or four of the substances experimented with were recommended for use in combating the coconut stem disease, and the experiments were conducted in order to demonstrate that they had no fungicidal action.

The spores were sown in flasks containing sugar cane extract, to which various percentages of the fungicide or other substance under experiment had been added. Flasks of about 40 c. c. capacity were used, and 20 c. c. of sugar cane extract containing 6 per cent. of sugar was placed in each. This was made up to 25 c. c. by the addition of the solution of the fungicide, together with the required quantity of water. The percentage of sugar, except where otherwise stated, was, therefore, 4·8. The experiments were usually conducted in duplicate, sometimes in quadruplicate.

A rather small supply of flasks prolonged the experiments, and made it impossible to use spores from the same culture throughout ; but in all cases they were taken from cultures six days old. Black, fully mature spores were therefore only used. Incubators were not available; and, therefore, the experiments were subject to a range of temperature of about 10° F., from 71° F. to 81° F. The range of temperature during a single experiment was less than this, at most 71–79° F., or 73–81° F.

Owing to repeated absences, it was impossible to make continuous observations on the progress of all the cultures. In many instances only final results can be given. But in all cases the cultures were left until there was no probability that any more in the series would develop. The results, therefore, give the concentration required to prevent the germination of the most resistant spores, which after all is what is required in estimating the value of a fungicide. It has been determined by other investigators that fungus spores from the same source vary greatly in their power of resistance ; and Stevens (18) states that an occasional spore may germinate and grow perfectly normally in a solution which prevents hundreds of

normal spores round it from germinating. From the appearance of the developing cultures, it would seem that a large proportion of *Thielaviopsis* spores germinated even in the strongest solution in which they germinated at all, but this point was not tested by observations in hanging drops, as the behaviour of the spores is not the same under the latter conditions.

In the following tables the first column gives the date of instituting the cultures and the percentage of the chemical in them; the others record the observed growth. The control culture was made with cane extract only. Where the growth is said to be good, the culture had reached the macroconidial stage and covered the surface of the liquid.

Potassium Nitrate.

Dec. 27. Percentage.	Dec. 29.	Dec. 30.	Dec. 31. Percentage.	Jan. 2.	Jan. 4.
·5	All growing well. Macroconidia forming.	Good growth in all.	6·0	Growth beginning in all.	Good
1·0			6·5		do.
1·5			7·0		do.
2·0			7·5		do.
2·5			8·0		do.
3·0			8·5		do.
Control	Good.		9·0		do.
			9·5		do.
			10·0		do.
			Control	Good.	

Jan. 5. Percentage.	Jan. 8.	Jan. 9.	Jan. 11.
10	Growth beginning.	Fair growth; macrospores.	Good growth.
12	Do.	Poor growth; macrospores.	Poor growth; macrospores.
14	Do.	do.	do.
16	Nothing.	Mycelium only.	Poor growth; only one small patch of spores.
18	Do.	Nothing.	Nothing up to January 14.
20	Do.	do.	do.
Control	Good.		

Penicillium subsequently developed in the 12 and 14 per cent. cultures.

Kainit.

A commercial sample of Kainit was employed. It was dried at 100° in a water oven. When dry it contained 4·8 per cent. of insoluble matter. This should therefore be deducted from the percentages given below. The percentage which inhibits germination is therefore 14–0·67 = 13·33, for this particular sample. The 17 per cent. solution was not alkaline.

Jan. 23. Percentage.	Jan. 26.	Jan. 27.	Jan. 28.
5	Nothing.	Slight growth; Stysanus form.	Fair growth.
6	Do.	do.	do.
7	Do.	Very slight development.	do.
8	Do.	do.	do.
9	Do..	do.	do.
10	Do.	do.	do.
Control	Good.		

Feb. 3.	Feb. 6.	Feb. 8.	Feb. 13.	Feb. 15–28.
11	Nothing.	Fair growth.	Fair.	Good.
12	Do.	Three small patches of mycelium.	Poor.	Fair.
13	Do.	Nothing.	Growth beginning.	Poor.
14	Do.	do.	Nothing.	Nothing.
15	Do.	do.	do.	do.
16	Do.	do.	do.	do.
17	Do.	do.	do.	do.
Control	Good.			

Temperature, 73–81° F.

Common Salt.

Ordinary Table Salt, dried at 100° C., was used.

Nov. 28. Percentage.	Dec. 1.	Dec. 8. Percentage.	Dec. 11	Dec. 14	Dec. 17. Percentage.	Dec. 21.	Dec. 23.
0·5	Good.	2	Good.	Good.	5	Fair.	Fair.
1·0	Do.	3	do.	do.	6	Poor growth.	Poor.
1·5	Do.	4	Fair	do.	7	Nothing.	Nothing.
2·0	Do.	5	do.	do.	8	do.	do.
Control	Do.	Control	Good.		9	do.	do.
					Control	Good.	

Temperature, 73–81° F.

Penicillium grew subsequently in the 7, 8, and 9 per cent. solutions on keeping.

Sodium Chloride.

Feb. 3. Percentage.	Feb. 5.	Feb. 6.	Feb. 8.	Feb. 9. Percentage.	Feb. 13.	Feb. 18.
1	Fair.	Good.	Good.	5	Nothing.	Poor growth.
2	Do.	do.	do.	6	do.	Nothing.
3	Moderate.	do.	do.	7	do.	do.
4	Nothing.	Nothing.	Moderate.	8	do.	do.
5	Do.	do.	do.	9	do.	do.
Control	Good.			Control	Good	

Temperature, 73–78° F.

Magnesium Sulphate.

Feb. 4. Percentage.	Feb. 6.	Feb. 8.	Feb. 9. Percentage.	Feb. 12.
1	All growing.	Good.	6	Good.
2		do.	7	do.
3		do.	8	do.
4		do.	9	do.
5		do.	10	do.
Control	—	do.	11	do.
			Control	do.

Feb. 19. Percentage.	Feb. 22.	Feb. 23.	Mar. 3. Percentage.	Mar. 5.	Mar. 6.	Mar. 8.
12	All growing.	Fair; macroconidia in all.	19	Slight growth in all, chiefly small patches with Stysanus form.	Fair	Good.
13			20		do.	do.
14			21		do.	do.
15			22		do.	do.
16			23		do.	do.
17			24		do.	do.
18			25		do.	do.
Control	Good.		Control	Good.		

This experiment was not continued further. Penicillium developed in the 23, 24, and 25 per cent. solutions.

Ferrous Sulphate.

Jan. 7. Percentage.	Jan. 11.	Jan. 13.
0·1	Mycelium only	Fair growth with Stysanus form
0·2	Nothing	Nothing
0·3	Do.	do.
0·4	Do.	do.
0·5	Do.	do.
Control	Good	

Zinc Sulphate.

Feb. 4. Percentage.	Feb. 6.	Feb. 8.	Feb. 13.
1	Nothing	Mycelium only	Poor growth with Stysanus form
2	Do.	Nothing	Nothing
3	Do.	do.	do.
4	Do.	do.	do.
5	Do.	do.	do.
Control	Good		

Temperature, 73–78° F.

Copper Sulphate.

Jan. 14. Percentage.	Jan. 16.	Jan. 18.	Jan. 19.	Jan. 22–26.
0·01	Growing	Good	Good	Good
0·02	Do.	do.	do.	do.
0·03	Nothing	Growing	Fair	Fair
0·04	Do.	Nothing	Nothing	Mycelium only
0·05	Do.	do.	do.	do.
0·06	Do.	do.	do.	do.
0·07	Do.	do.	do.	Nothing
0·08	Do.	do.	do.	do.
0·09	Do.	do.	do.	do.
0· 1	Do.	do.	do.	do.
Control	Good			

Temperature, 72–82° F.

The spores from the last four cultures (0·07–0·1) were transferred after twelve days' immersion to pure sugar cane extract, where they developed an excellent growth in all cases in three days.

Mercuric Chloride.

Mar. 12. Percentage.	Mar. 22.
·01	No growth
·02	
·03	
·04	
·05	
·06	
·07	
·08	
·09	
· 1	
Control	Good

Mar. 27. Percentage.	Mar. 29.	Mar. 30.	April 1.
·001	Fair	Good	Good
·002	Nothing	Slight	do.
·003	do.	Nothing	Nothing
·004	do.	do.	do.
·005	do.	do.	Kept until April 12.
·006	do.	do.	do.
·007	do.	do.	do.
·008	do.	do.	do.
·009	do.	do.	do.
· 01	do.	do.	do.
Control	Good		

The spores from the first ten cultures were transferred to pure sugar cane extract, March 23, but no growth resulted.

Potassium Hydrate.

Dec. 23. Percentage.	Dec. 27.	Litmus re-action.
0·1	Good	Feebly acid
0·2	Do.	do.
0·3	Poor	Feebly alkaline
0·4	None	Distinctly alkaline
0·5	Do.	do.
0·6	Do.	do.
0·7	Do.	do.
0·8	Do.	do.
0·9	Do.	do.
1·0	Do.	do.
Control	Good	Acid

Kept to January 4; no further development.

Sodium Hydrate.

Jan. 27. Percentage.	Observation. Jan. 29.	Observation. Feb. 1.	Litmus re-action.
0·1	Growing	Good	Feebly acid
0·2	Nothing	Nothing	Alkaline
0·3	Do.	do.	do.
0·4	Do.	do.	do.
0·5	Do.	do.	do.
Control	Good	—	Acid

Kept to February 8; no further development.

The last two experiments agree in showing that the growth of *Thielaviopsis* is inhibited directly the solution becomes distinctly alkaline.

Hydrochloric Acid.

June 17. Percentage.	June 19.	June 23.
0·01 / 0·02 / 0·03	Good growth of mycelium, with a few microconidia ..	.. Good
0·04 / 0·05	Good growth of mycelium, with Stysanus form ..	.. do.
0·06	.. Fair growth, with few microconidia	.. do.
0·07	.. Slight growth, with microconidia	.. Fair
0·08	.. Do. do.	.. do.
0·09	.. Small suspended tufts of mycelium	.. do.
0· 1	.. Do. do.	.. do.
0· 2	.. Minute spheres of mycelium	.. Spheres of mycelium
0· 3	.. Nothing ..	.. One sphere of mycelium
0· 4	.. Do. ..	.. Nothing up to June 30
0· 5	.. Do. ..	.. do.
Control	.. Good	

Temperature, 75–79° F.

In this and the next series the last two cultures which germinated produced submerged compact spheres of mycelium which bore large numbers of suppressed macroconidia only, usually one on each conidiophore.

Sulphuric Acid.

June 17. Percentage.	June 19.	June 23.	June 30.
0·01 / 0·02 / 0·03	Good growth of mycelium with some macro- and micro-conidia	.. Good	
0·04	.. Fair growth; micro-conidia only	.. do.	
0·05	.. Tufts of mycelium only	.. Fair	
0·06	.. Minute tufts of mycelium	.. do.	
0·07 / 0·08	.. Do. / .. Do.	Poor growth with macroconidia	
0·09 / 0· 1	.. Nothing / .. Do.	Submerged tufts of mycelium	Tufts bearing macroconidia
0· 2	.. Do.	.. Nothing	Nothing up to June
0. 3	.. Do.	.. do.	
0. 4	.. Do.	.. do.	
0. 5	.. Do.	.. do.	
Control	.. Good		

Temperature, 75–79° F.

Acetic Acid.

June 17. Percentage.	June 19.	June 23.
0·01	Good growth of mycelium	Good
0·02	Fair growth, with microconidia	do.
0·03	Do.	do.
0·04	Fair; few microconidia	do.
0·05	Do.	do.
0·06	Do.	do.
0·07	Do.	do.
0·08	Fair; very few microconidia	do.
0·09	Small suspended tuft of mycelium	do.
0· 1	Minute growth of mycelium	Fair
0· 2	Nothing	Nothing up to June 30
0· 3	Do.	
0· 4	Do.	
0· 5	Do.	
Control	Good	

Temperature, 75–79° F.

Lactic Acid.

Sept. 27. Percentage.	Sept. 30.	Oct. 1.	Oct. 2.
0·5	Poor; Stysanus form	Fair	Fair
1·0	Nothing	Beginning	Stysanus form
1·5	Do.	Nothing	Nothing to Oct. 13
2·0	Do.	Nothing	do.

Tannic Acid.

As a preliminary experiment, spores were sown in sugar cane solution to which 1 per cent. tannic acid had been added. There was no trace of tannic acid in the original solution. The control culture showed good growth in two days, but there was no growth after ten days in the tannic acid culture. The spores from this culture were transferred to sugar cane extract, and produced a good growth of macroconidia within five days. Temperature, 71–78° F. Further cultures were then made, as follows :—

Nov. 23. Percentage.	Observation. Nov. 27.	Observation. Nov. 28.	Observation. Dec. 4.
0·05	Good	Good	Good
0· 1	Do.	do.	do.
0· 2	Do.	do.	do.
0· 3	Growing	Moderate	Fair
0· 4	Nothing	Nothing	Nothing
0· 5	Do.	do.	do.
Control	Good		

This experiment was repeated with the same sugar cane extract, diluted to contain half the previous percentage of sugar, with the following results :—

November 24. Percentage.		Observation. November 27.		Observation. November 28.		Observation. December 4.
0·05	..	Good	..	Good	..	Good
0·1	..	Do.	..	do.	..	do.
0·2	..	Fair	..	Fair	..	Fair
0·3	..	Growing	..	do.	..	do.
0·4	..	Nothing	..	Nothing	..	Nothing
0·5	..	Do.	..	do.	..	do.
Control	..	Good				

Temperature, 75·5–79·5° F.

The dry weight of *Thielaviopsis* in the control culture on December 4 was 0·044 grams; that in the 0·1 per cent. tannic acid culture was 0·025 grams. 0·3 per cent. of tannic acid is the limiting percentage in both cases, *i.e.*, the difference in the percentage of food in the solution does not alter the percentage of tannic acid required to inhibit growth. This is in accordance with the known behaviour of other chemicals on different fungi. It will be noted from the preliminary experiment that the spores are not killed by tannic acid, even if the percentage employed is more than three times that required to prevent the growth of the fungus.

It was thought that the marked influence of a small percentage of tannic acid upon the growth of the fungus might serve to explain why the disease does not attack the bud of the coconut, but subsequent analyses have shown that there is no tannic acid in coconut tissues.

Gallic Acid.

(This contained traces of Tannic Acid.)

December 10. Percentage.	Observation. December 12.	Observation. December 14.
0·1, 0·2, 0·3, 0·4, 0·5	Growth beginning in all	Excellent growth in all
Control		

December 17. Percentage.	Observation. December 21.	Observation. December 22.
0·6	Good	Good
0·7	Fair	do.
0·8	Do.	do.
0·9	Do.	Fair
1·0	Poor	do.
Control	Good	

Temperature, 73–81° F.

December 23. Percentage.	December 27.	December 31.
1·1	Poor	Good
1·2	Do.	do.
1·3	Do.	do.
1·4	Do.	do.
1·5	Slight development of mycelium	Fair ; Stysanus form
1·6	Do.	do.
1·7	Nothing	Poor ; Stysanus form
1·8	Do.	do.
1·9	Do.	do.
2·0	Do.	do.
Control	Good	

Temperature, 73–79° F.

January 4. Percentage.	January 11.	January 15.
2·0	Fair	Fair
2·1	Slight development of mycelium	Poor ; Stysanus form
2·2	Do.	do.
2·3	Do.	do.
2·4	Nothing	Nothing
2·5	Do.	do.
Control	Good	do.

Temperature, 73–79° F.

Carbolic Acid.

January 5. Percentage.	January 18.	January 20.	January 22–26.
0·01	Good	Good	Good
0·02	Do.	do.	do.
0·03	Fair	do.	do.
0·04	Do.	do.	do.
0·05	Do.	do.	do.
0·06	Beginning	do.	do.
0·07	Do.	Fair	do.
0·08	Nothing	Moderate	Fair
0·09	Do.	do.	do.
0·1	Do.	Nothing	Small patch of submerged mycelium about 5 mm. diameter
Control	Good		

January 23. Percentage.	January 26.	January 28–February 1.
0·1	Nothing	Submerged mycelium about 2 mm. diameter
0·11	Do.	Nothing
0·12	Do.	do.
0·13	Do.	do.
0·14	Do.	do.
0·15	Do.	do.
Control	Good	

The spores and mycelium from the last six cultures were transferred to pure cane extract on February 4, after twelve days' immersion. The first three produced a good growth, with macroconidia, in two days, and the remaining three were then beginning to grow. All showed a good growth, with macroconidia, in four days.

Formaldehyde.

September 4. Percentage.	September 13.
0·01	No growth
0·02	No growth
0·03	No growth
0·04	No growth
0·05	No growth
0·06	No growth
0·07	No growth
0·08	No growth
0·09	No growth
0·1	No growth
Control	Good

October 2. Percentage.	Oct. 8.	Oct. 15.
0·001	Good	Good
0·002	do.	do.
0·003	do.	do.
0·004	do.	do.
0·005	Growing	do.
0·006	Good	do.
0·007	Nothing	Nothing
0·008	do.	do.
0·009	do.	do.
0·01	do.	do.
Control	Good	

Spores from the first ten cultures were transferred to pure cane extract on September 16, after twelve days' immersion; no growth resulted.

The following table summarizes the results of the foregoing experiments. The first column gives the highest percentage in which the fungus grew, while the second gives the lowest observed percentage in which no growth occurred. The third and fourth columns give the same quantities converted into fractions of a "normal solution,"

i.e., a solution which contains the molecular weight in grams in a litre :—

	Growth in.	No Growth in.	Growth in.	No Growth in.
	Per cent.	Per cent.		
Potassium nitrate ..	16	18	1·57 N	1·77 N
Sodium chloride ..	5	6	0·85 N	1·02 N
Magnesium sulphate ..	25+	—	1 N	—
Ferrous sulphate ..	0·1	0·2	0·0036 N	0·0072 N
Zinc sulphate ..	1·0	2·0	0·035 N	0·07 N
Copper sulphate ..	0·06	0·07	0·0024 N	0·0028 N
Mercuric chloride ..	0·002	0·003	0·000074 N	0·00011 N
Potassium hydrate ..	0·3	0·4	0·053 N	0·071 N
Sodium hydrate ..	0·1	0·2	0·024 N	0·048 N
Hydrochloric acid ..	0·3	0·4	0·082 N	0·1 N
Sulphuric acid ..	0·1	0·2	0·01 N	0·02 N
Acetic acid ..	0·2	0·3	0·033 N	0·05 N
Lactic acid ..	1·0	1·5	0·11 N	0·16 N
Carbolic acid ..	0·1	0·11	0·011 N	0·012 N
Tannic acid ..	0·3	0·4	0·008 N	0·011 N
Gallic acid ..	2·3	2·4	0·12 N	0·13 N
Formaldehyde ..	0·006	0·007	0·002 N	0·0023 N

In most of the recorded investigations into the action of toxic substances on fungus spores, the concentration required to prevent germination is all that has been determined. But it is clear from the foregoing records, *e.g.*, with tannic acid, carbolic acid, and copper sulphate, that the spores are not killed by much higher percentages of the toxic substance than are required merely to inhibit germination. Further, it is evident that the spores, when placed in a nutrient solution which contains a toxic substance in excess of the inhibiting percentage, do not germinate and die, as is frequently supposed: they merely remain dormant. Whether they ultimately die depends on the percentage of the fungicide and the duration of immersion.

These points are of considerable importance in regard to the action of fungicides on fungus spores. Determinations based only on the non-germination of the spores give scarcely any information as to the actual fungicidal value of the fungicide. Copper sulphate, for example, in a concentration of 0·07 per cent., prevents the germination of *Thielaviopsis*, but, as

will be shown later, its actual fungicidal value, tested by its power of killing the spores, is not great in this case.

It is usually supposed that when plants are sprayed with a fungicide, they are protected from the attacks of fungi, because the fungicide kills any spores which may alight upon the sprayed leaves. How this action occurs is a matter of doubt. One view holds that the spores are actually killed by contact with the fungicide ; this may be true of thin-walled spores, but it is improbable with thick-walled spores, such as *Thielaviopsis*, unless the period of contact extended over several months. Another view is that the spores germinate, and that the developing mycelium is killed by the fungicide. This latter view would appear to be disproved by the experiments with copper sulphate already quoted. It would seem that the spores of *Thielaviopsis* would remain dormant in contact with such a fungicide ; and would germinate when the fungicide were washed away, provided that the exposure to its action had not been too prolonged.

In the experiments described below, the spores were immersed in a solution of known strength, and were transferred at regular intervals to a nutrient solution, viz., sugar cane extract. Obviously, by varying the concentration of the fungicide, such experiments can be carried on indefinitely ; but as little time was available it was necessary to restrict them to those percentages which are commonly employed.

The spores, except where otherwise stated, were taken from cultures six days old. The mass of spores and mycelium was transferred to a glass cylinder, 8 cm. high and 4 cm. diameter, where it was torn into small pieces with needles, and pounded with a glass rod to moisten the spores. The cylinder was then placed in a basin, and the fungicide was poured into it and allowed to overflow. Any floating spores were then rapidly wiped off with a piece of filter paper. When the spores alone were being tested, the liquid was poured into another similar cylinder after the fragments of mycelium had settled ; by this procedure, the liquid could be periodically stirred without any danger of obtaining spores which had been protected by the mycelium. When it was wished to take samples at short intervals, the culture was divided into three parts, and the

three series of tests, as described below, were carried out separately. With copper sulphate, and in some instances with carbolic acid, where the experiment was prolonged for several weeks, the fungicide and spores, or mycelium, was kept in wide-mouthed stoppered bottles.

Spores were transferred by means of a straight platinum wire to hanging drops of sugar cane extract. They were also transferred by means of a platinum loop to flasks of the same medium. The former was adopted in order to transfer as small an amount of the fungicide as possible with the spores; the wire was merely dipped in the mixture. In addition, small fragments of mycelium containing spores were transferred to sugar cane extract; this was done with a hooked platinum wire and as small a quantity as possible was transferred; in general, it did not exceed 0·5 mm. in diameter when collapsed on the wire; but no exact results can be expected by this last method, since it is usually possible to obtain a germination by transferring a larger quantity of mycelium. *Thielaviopsis* is peculiar in that some spores remain within the conidiophores, and apparently these are protected from the action of the fungicide for an indefinite period.

In making transfers per minute, the mixture was stirred immediately after a sample had been taken and then allowed to settle. In other cases it was stirred shortly before the transfer was made. From observed weights of previous cultures, it was estimated that in no case would the dry weight of a culture exceed 0·5 grams; as a rule the cultures were divided into three, and the mass of spores or mycelium was therefore small in comparison with the volume of the fungicide. In the case of copper sulphate, when the experiment was of several weeks' duration, 200 c. c. of the fungicide was used with not more than 0·2 grams (dry weight) of mycelium and spores.

Mercuric Chloride, 0·1 per Cent.

(1) As a preliminary experiment, the spores were immersed in this solution and transferred by a platinum loop every minute to flasks of sugar cane extract. The spores transferred

in the first four minutes produced a fair growth in three days, but nothing resulted from the transfers at the end of the fifth and the succeeding twenty minutes. In this case, therefore, the spores were killed by an immersion of five minutes.

The growth of the first four cultures was somewhat slower than is usual with normal spores, but not markedly so ; and there was no difference between the four cultures.

(2) Culture divided into three parts treated separately :—

(*a*) Spores transferred to hanging drops by a straight platinum wire after two minutes' immersion, and every subsequent minute for ten minutes ; then every two minutes for twenty minutes. No germination in five days.

(*b*) Spores transferred to flasks by a platinum loop after two minutes' immersion, and every minute for ten minutes; then every two minutes for twenty minutes, every five minutes for the next half hour, and every fifteen minutes for one hour. After two days, growth in Nos. 1, 2, and 8; good growth in these three at the end of five days. These spores therefore survived immersion for two, three, and ten minutes respectively. Total period of transfers, two hours. Growth was considerably retarded.

(*c*) Mycelium and spores transferred to flasks of sugar cane extract. First transfer after eight minutes' immersion; subsequently every two minutes up to one hour, and then at intervals of ten to fifteen minutes for two hours. No growth in any in six days. Total period of transfers three hours.

(3) Culture, nine days old, instituted at the same time as (2), and from the same spores, separated into three parts, treated separately :—

(*a*) Spores transferred to hanging drops by a straight platinum wire every fifteen seconds for two minutes. No germination in five days.

(*b*) Spores transferred to flasks by platinum loop ; every thirty seconds for six minutes. No growth in two days ; microconidia in Nos. 2 and 7 after three days.

Good growth is Nos. 2 and 7 after four days. These spores therefore survived immersion for one and three and a half minutes respectively.

(*c*) Mycelium and spores transferred to flasks, every thirty seconds for ten minutes. Poor growth in Nos. 1, 2, and 3 after two days. Fair in 1, 2, 3; poor but black in 4 and 5; still white in 6; nothing in 7; poor but black in 8—after three days. Good growth in 1–6 and 8, after five days. No further development. These spores therefore germinated regularly up to the end of three minutes' immersion; the sample taken after three and half minutes was dead, but those taken after four minutes germinated.

At the end of six days, fresh spores of *Thielaviopsis* were sown in several of the hanging drops and flasks in which no growth had occurred, to determine whether this was due to the amount of mercuric chloride transferred with the spores. In all cases these spores germinated and the fungus developed normally.

The growth of the fungus is usually considerably retarded by the previous immersion of the spores. In 3 (*b*) the growth in four days was about equal to a normal two days' growth; while in 3 (*c*) the same stage was reached in three days by the earlier and four days by the later transfers.

Summarizing the experiments with 0·1 per cent. mercuric chloride, we have the following results:—

(*a*) Spores transferred to hanging drops do not germinate after an immersion of fifteen seconds.

(*b*) Spores transferred to flasks germinated in no case after eleven minutes' immersion. In one case no growth occurred after five minutes; in another, the majority were killed by four minutes' immersion, but some survived ten minutes; in the third case, some were killed by an immersion of thirty seconds, others survived one minute's immersion, most were killed by one and half minutes, but some survived three and half minutes.

(*c*) Transfers of mycelium and spores show the same irregularity as transfers of spores only. In one case no growth was obtained after an immersion of eight

minutes, though the spores alone germinated after an immersion of ten minutes. In the other, transfers of mycelium and spores failed to grow after four and half minutes' immersion, while the spores alone did not survive four minutes. Experiments with other fungicides usually show that the spores in the mycelium, as would be expected, survived a longer immersion than the spores alone ; but even that does not hold good in the present case.

It has been shown previously by Brooks (19) that the concentration of the toxic agent required to produce injury in flasks is greater than that required in hanging drops. Apparently a similar rule is true in the present case, viz., that spores subjected to immersion in a toxic solution will grow in flasks when they will not grow in hanging drops. To whatever cause this may be due, it is evident that in order to determine whether spores are dead they should be tested in flask cultures, not in hanging drops.

The impossibility of obtaining a sample of spores, all of the same power of resistance, introduces a large element of chance into such experiments as those described above. For example, we may imagine that a given sample consists chiefly of spores which would be killed by an immersion of two minutes, in a certain fungicide, but contains a few which would survive ten minutes but be killed by eleven minutes. If the latter spores happened to be all taken in the first minute, the death point of the whole sample would be two minutes. Similarly, if none of them were taken in the first eleven minutes, the death point of the whole would again be two minutes. And, of course, all other numbers from two to ten would be possible. The heterogeneity of the material renders any uniform result impossible.

Formaldehyde, 1·0 per Cent.

(1) As a preliminary experiment, spores from a six days old culture were immersed in 1·0 per cent. formaldehyde, and transferred at intervals to flasks of pure cane extract by means of a platinum loop. Transfers 1–20 were made at intervals of one minute, 21–28 at intervals of five minutes, and 29–37 at intervals of fifteen minutes. Further transfers

were made, extending over the next two days. Nos. 1 and 2 began to grow two days after the transfer, and produced a good growth of macroconidia, &c., on the following day. There was no growth in any of the remaining flasks, though they were kept for ten days. These spores therefore survived an immersion of two minutes, but were killed by an immersion of three minutes.

(2) Culture six days old, divided into three parts which were treated separately :—

(*a*) Spores transferred to hanging drops by a straight platinum wire every fifteen seconds for two minutes, and every thirty seconds for the succeeding four minutes. Examined two days later, transfers 1–4 showed good growth, 5 was fair, and there was a slight growth in 6 ; in the remaining ten no spores had germinated. On the third day, the spores in transfers 7 and 8 had germinated, but there was no growth in 9–16. Nothing further occurred. These spores therefore survived an immersion of two minutes, but were killed by an immersion of two and a half minutes. Isolated spores in transfers 7 and 8 germinated.

(*b*) Spores transferred to flasks of sugar cane extract by means of a platinum loop. Transfers made every thirty seconds for five minutes, and every minute for the succeeding twenty-five minutes. Growth occurred in all flasks up to and including No. 13. These spores therefore survived an immersion of eight minutes, but were killed by an immersion of nine minutes (see below).

(*c*) Mycelium transferred to flasks of sugar cane extract, every minute for twenty minutes, then at intervals of five minutes for the next forty minutes, and subsequently at intervals of fifteen minutes for the next six hours. All transfers up to and including No. 12 grew, 13 failed, 14 and 15 grew, 16 failed, 17 grew ; the remainder all failed. The spores of No. 17 thus survived an immersion of seventeen minutes.

In 2 (*a*) it will be noted that the germination of the surviving spores in transfers 7 and 8 was retarded by one day in comparison with transfer 6 of the same series and nearly three

days in comparison with normal *Thielaviopsis* spores. This point is particularly well illustrated by an examination of the detailed results of (*b*) and (*c*). These are given below, the days being the number of days since the transfer of the spores.

(*b*)—

2 days. No. 1, fair growth, but white ; No. 2, growing.

3 days. No. 1, good ; No. 2, fair ; Nos. 3 and 4, growing.

4 days. Nos. 1 and 2, good ; Nos. 3 and 4, fairly good.

5 days. Nos. 1–4, good ; Nos. 5 and 6, growing.

6 days. Nos. 1–6, good ; No. 7, growing ; No. 11, growing.

7 days. No. 7, fair ; Nos. 8 and 9, growing ; No. 11, fair.

8 days. No. 7, good ; No. 8, fair ; No. 9, mycelium only ; No. 10, growing ; No. 11, good.

9 days. No. 9, good ; No. 10, fair but white ; No. 11, good.

This was not examined again until forty days from the time of transfer ; Nos. 12 and 13 had then developed a good growth.

(*c*)—

2 days. No. 1, fair.

3 days. No. 1, good ; No. 2, growing.

4 days. Nos. 1 and 2, good ; No. 3, growing.

5 days. Nos. 1 and 2, good ; No. 3, fair ; No. 4, growing.

6 days. Nos. 1–4, good.

7 days. No. 5, growing.

8 days. No. 5, fair ; No. 6, growing.

9 days. No. 5, fairly good ; No. 6, fair but white ; No. 7, growing, but not above surface of liquid.

As with (*b*), this was not examined further until forty days had elapsed from the time of transfer. Every transfer had then developed up to and including No. 17, except Nos. 13 and 16.

It is clear from these records that this retardation is not due to a diminished rate of growth after the germination of the spores. In each case the culture has produced a good growth of mycelium, covering the whole surface, and has arrived at the macroconidial stage, within two days of germination, as is usual with untreated spores. The retardation is therefore due to a delayed germination ; this conclusion is confirmed by the results of 2 (*a*).

This result is extremely important, in that it indicates the necessity of a more prolonged examination than is usually

given when estimating the effect of a fungicide upon fungus spores. Brooks (19) states that his charts of results are based entirely upon the data secured on the first and second days after transferring, and that in very few instances did spores germinate on the second day. In the present instance any arbitrary limitation of the period of observation to two or three days would certainly have resulted in an entirely erroneous estimate of the fungicidal value of formalin. To arrive at the true value the cultures must be left until no further germination occurs. This retardation of germination is more marked with formalin than with any of the other substances tested in this series of experiments. A 0·1 per cent. solution of formaldehyde is now being largely recommended as a disinfectant for seeds, but in view of the foregoing results it would seem that its retarding effect has been mistaken for actual killing. In a recent study of the fungi occurring on wheat stems, it is stated that the stems "were sterilized by treating one minute with 1 per cent. formaldehyde, and afterwards washing with sterile distilled water. Thus it is presumed that all saprophytes and surface fungi were eradicated." As the fungi in question included species of *Macrosporium* and *Helminthosporium*, it is highly probable that this method is fallacious.

Carbolic Acid, 1·0 per Cent.

(1) As a preliminary experiment, the spores were immersed in the solution in the manner already described, and transferred by a platinum loop every five minutes for one hour, and at the end of every hour for the succeeding twelve hours. The spores transferred after five minutes' immersion developed a good growth in two days, while those transferred after ten minutes' immersion developed a good growth in three days. No growth occurred in any of the remaining flasks. The spores were therefore killed by an immersion of between ten and fifteen minutes.

(2) An attempt was next made to determine whether the age of the culture affected the time required to kill the spores. Three cultures were employed: the first eight days old, the second twenty days, and the third thirty-three days. The spores were transferred as above by a platinum loop. In the

first, transfers were made every minute for twenty-six minutes; in the second, every minute for thirty-two minutes; in the third, every minute for forty minutes. As the spores were killed by an immersion of fifteen minutes in the previous experiment, it was expected that these times would be amply sufficient, but contrary to this expectation all the transfers grew well, and therefore no result was arrived at.

(3) Culture, six days old, divided into three parts which were treated separately :—

(*a*) Spores transferred to hanging drops by means of a straight platinum wire. Transfers made every five minutes for the first hour, every ten minutes for the second hour, and every fifteen minutes for the fifth, sixth, and seventh hours. No spores germinated after the eighth transfer. They, therefore, survived an immersion of forty minutes, but were killed by an immersion of forty-five minutes. Germination of isolated spores occurred in all transfers up to the eighth; in the latter, 50 per cent. of the isolated spores and 53 per cent. of the spores in groups germinated within twenty-four hours.

(*b*) Spores transferred by platinum loop to flasks of cane extract. Transfers as above. All transfers grew up to No. 20, *i.e.*, after an immersion of two hours twenty minutes; all subsequent transfers failed. Unfortunately, No. 21 was transferred only after an immersion of four hours and forty-four minutes.

(*c*) Mycelium and spores transferred by platinum wire to flasks. First transfer after an immersion of one hour, then every ten minutes for the second hour, every fifteen minutes for the fifth, sixth, and seventh hours, then every hour to the end of the twelfth hour, and again every hour from the twentieth to the twenty-fifth hour. As in the case of (*b*) all the transfers grew up to No. 20. The death point lies therefore between two hours twenty minutes and four hours and forty-four minutes.

(4) The last experiment was repeated with another culture, six days old, in the expectation of obtaining a closer

approximation to the actual times required to kill the spores :—

(*a*) Spores were transferred by a straight platinum wire to hanging drops. Transfers made every minute for the first twenty minutes, and then every two minutes for the next forty minutes. Examined twenty-four hours afterwards, germinated spores were found in all the transfers. These spores, therefore, survived an immersion of one hour, and the death point was not reached.

(*b*) Spores transferred by platinum loop to flasks of sugar cane extract. Transfers 1–40 as above, then every ten minutes for two hours, and every fifteen minutes for four hours. All transfers grew, up to and including that at six hours thirty minutes; the two succeeding transfers failed, as did also those transferred on the following day.

(*c*) Mycelium and spores transferred by platinum wire to flasks of sugar cane extract. Transfers were made at intervals of ten to fifteen minutes until seven hours had elapsed, and others were made on the following morning after twenty-four hours' immersion. All the former transfers grew well, but none of the latter. These spores, therefore, survived immersion for seven hours, but were killed by an immersion of twenty-four hours.

These experiments with carbolic acid were not carried further. The results given above show that no uniformity in the period required to kill the spores can be obtained by any of these methods, and that it is impossible from experiments with one sample of spores to forecast even approximately the behaviour of the next. Spores transferred to hanging drops were in one case killed by an immersion of forty-five minutes, but those from another culture of the same age survived an immersion of sixty minutes, and probably longer. Spores transferred to flask cultures were killed in one case in fifteen minutes; in three other cases they survived an immersion of twenty-five, thirty-two, and forty minutes, respectively, no death point being reached; in a fifth case they survived an immersion of two hours twenty minutes, but were killed by four hours forty-four minutes, no intermediate transfers being made;

while in a sixth case, they were killed by an immersion of six hours forty-five minutes, but as the experiment was only carried on for another transfer (at seven hours) this result is doubtful. Transfers of mycelium plus spores were killed in one case between two hours twenty minutes and four hours forty-four minutes, but in the subsequent experiment to determine a more approximate death point they survived an immersion of seven hours.

No agreement was expected between the results obtained by the three methods, and it is clear that the results of the third method depend upon the size of the masses of mycelium transferred. For example, after twenty-four hours' immersion in 1 per cent. carbolic acid all transfers of small fragments of mycelium failed to grow, but growth was obtained from a larger mass in the same solution. But there does not seem to be any explanation of the variation in the results obtained by transferring the spores alone, except on the supposition that the spores vary in their power of resistance to the fungicide. The spores are comparatively large, and are easily wetted by the liquid. Examination of the hanging drops showed that in no case did groups of spores enclose air bubbles, and tests of the loop transfers gave the same result: it is improbable, therefore, that the variation is due to this cause.

Copper Sulphate.

(1) A flask culture, six days old, was divided into two parts, one of which was torn up in 1 per cent. carbolic acid, and the other in 1 per cent. copper sulphate. The two bottles containing the mixtures were then placed under an air pump, and any air in the mycelium extracted. Transfers were made to flasks of sugar cane extract every twenty-four hours for thirty-five days. No growth was obtained in any of the transfers from carbolic acid. In the case of the copper sulphate, good growth resulted in all transfers up to the nineteenth; the twentieth, twenty-first, and twenty-fourth failed, but the subsequent transfers grew up to the twenty-seventh; no growth was obtained from the twenty-eighth and seven following transfers. Germination was delayed about two days in the last living transfers. Judged by this experiment the killing power of copper sulphate is small compared

with that of carbolic acid, though the former is the more efficacious in inhibiting germination.

(2) A flask culture, six days old, was divided into three parts, which were shredded in 5, 4, and 3 per cent. copper sulphate, respectively. Transfers of fragments of mycelium containing spores were made every twenty-four hours to flasks of sugar cane extract. The experiment was prolonged for one hundred and thirteen days. From the 5 per cent. solution all the transfers grew until the forty-fifth day; subsequently growth occurred in the transfers on the forty-ninth, fiftieth, fifty-first, fifty-fourth to fifty-seventh, sixty-second, sixty-sixth, sixty-seventh, seventy-third, seventy-fifth, and eighty-second days. In the eighty-second transfer, the spores germinated in five days and produced a fair growth in eight days, as compared with two days from untreated spores. From the 4 per cent. solution, all the transfers grew until the sixty-fifth day; failures occurred on the sixty-fifth, seventy-sixth, eighty-first, eighty-second, eighty-fourth, eighty-sixth, eighty-seventh, ninety-second, ninety-third, ninety-fifth to ninety-eighth, and one hundredth days; the one-hundred and first transfer was the last that grew. From the 3 per cent. solution, the first failure occurred on the forty-fifth day, as in the case of the 5 per cent. solution; further failures occurred on the forty-ninth, fifty-second, fifty-seventh, sixty-first, sixty-third, sixty-sixth, sixty-eighth, seventy-first to seventy-fourth, seventy-sixth to eighty-fourth days; the eighty-fifth was the last transfer which grew.

(3) A culture, eight days old, was divided into five parts, which were shredded in 1, 2, 3, 4, and 5 per cent. copper sulphate respectively. The mixtures were shaken up and allowed to stand until the mycelium had sunk to the bottom. The liquids with the suspended spores were then decanted into other bottles, and fresh copper sulphate solutions of the same strength were added to the mycelium. The bottles containing the latter were put aside, and spores were transferred every twenty-four hours by means of a platinum loop from the bottles which contained spores only. The experiment was continued for twenty-eight days. From the 5 per cent. solution, the first and second transfers failed, but the third

grew ; this was the only transfer which grew. From the 4 per cent. solution, the first, second, fifth, and sixth grew. From the 3 per cent. solution all grew, up to and including the tenth ; the eleventh to the sixteenth failed, but the seventeenth grew. From the 2 per cent. solution all grew up to and including the eleventh; the twelfth and thirteenth failed, but the fourteenth grew. From the 1 per cent. solution all grew up to and including the ninth ; the tenth failed, but the eleventh grew; the twelfth and thirteenth failed, but the fourteenth grew ; the fifteenth to the nineteenth failed, but the twentieth grew.

The samples of mycelium and spores, which had been put aside in copper sulphate solutions, were tested by transference on the thirtieth and following days. No growth was obtained from the 4 and 5 per cent. solutions. Growth from the other three solutions occurred up to and including the seventieth day, after which the experiment was discontinued.

(4) This experiment was repeated with a culture six days old, and 4 and 5 per cent. solutions of copper sulphate. As some of the spores were dead in the 5 per cent. solution after twenty-four hours in experiment 3, transfers were made at intervals during the first day. The first failure of the spores transferred from the 4 per cent. solution occurred on the fourth day ; the transfers grew on the fifth to the eighth day, but failed on the ninth ; they grew on the tenth but failed on the eleventh and twelfth ; the transfer on the thirteenth day was the last that grew. From the 5 per cent. solution all the transfers grew, up to and including that on the fifth day. The experiment was continued for twenty days.

As in experiment 3, the mycelium and spores which had been kept in separate bottles of copper sulphate solution were also transferred. From the 5 per cent. solution, growth occurred in transfers on the twenty-fourth, twenty-ninth, fortieth, and fiftieth days, no intermediate transfers being made ; no further test was made until the sixty-sixth day, when, and on subsequent days, all the spores were found to be dead. From the 4 per cent. solution growth occurred on the sixty-sixth day, and in various transfers up to and including the ninetieth day ; a transfer on the one-hundredth day failed. The experiment was not continued further.

The following table gives the results of these experiments. The times quoted are *maximum* times required to kill the spores :—

		Transfers of: Spores to Hanging Drops.	Transfers of: Spores to Flasks.	Transfers of: Mycelium and Spores to Flasks.
Mercuric chloride 0·1 per cent.	(1)	—	5 minutes	—
	(2)	< 2 minutes	11 minutes	< 8 minutes
	(3)	< 15 seconds	4 minutes	4½ minutes
Formalin 1 per cent.	(1)	—	3 minutes	—
	(2)	2½ minutes	9 minutes	18 minutes
Carbolic acid 1 per cent.	(1)	—	15 minutes	—
	(2a)	—	> 26 minutes	—
	(2b)	—	> 32 minutes	—
	(2c)	—	> 40 minutes	—
	(3)	45 minutes	> 2 hours 20 minutes < 4 hours 44 minutes	> 2 hours 20 minutes < 4 hours 44 minutes
	(4)	> 1 hour	6 hours 45 minutes	> 7 hours < 24 hours
Copper sulphate 1 per cent.	(1)	—	—	28 days
	(3)	—	21 days	> 70 days
2 per cent.	(3)	—	15 days	> 70 days
3 per cent.	(2)	—	—	86 days
	(3)	—	18 days	> 70 days
4 per cent.	(2)	—	—	102 days
	(3)	—	7 days	< 30 days
	(4)	—	14 days	> 90 < 100 days
5 per cent.	(2)	—	—	83 days
	(3)	—	4 days	< 30 days
	(4)	—	6 days	> 50 < 66 days

Transfers of spores from copper sulphate to hanging drops of cane extract were not made.

The lack of any uniformity in the foregoing figures is in striking contrast to the regularity observed in the experiments on the inhibition of germination by toxic agents, &c. In the latter, it was possible to carry an experiment on up to a certain percentage, and then to begin another series at that percentage with a different sample of spores, with the certainty that the first result would be repeated. For instance, spores sown in a nutrient medium with 0·1 carbolic acid produced submerged mycelium only ; in another series, beginning with 0·1 per cent. carbolic acid, the same result was obtained. Gallic acid and sodium chloride provide two other examples. Moreover, in the preliminary tests, it was determined whether the fungus would grow in solutions which contained 0·5, 1·0, and 1·5 per cent. of the toxic agent ; and in no case did the limit in the succeeding experiment exceed that found in the preliminary test, though the former was made with another sample of spores. Apparently, therefore, the percentage of a toxic agent which will inhibit germination is about the same for all samples of spores, but the time required to *kill* the spores by a given percentage differs with different samples.

From the table on page 571, the order of the four substances arranged according to their fungicidal value is mercuric chloride, formalin, carbolic acid, copper sulphate. Arranged according to their power of inhibiting germination, the order is mercuric chloride, formalin, copper sulphate, carbolic acid. With *Thielaviopsis* at least the real fungicidal value of copper sulphate is remarkably low.

Though no definite result was obtained in this second series, the following conclusions appear to be warranted by the foregoing experiments :—

(1) Tests of fungicides, which determine only the percentage required to prevent germination, do not give a true idea of their actual or relative fungicidal value.

(2) Spores which are subjected to the action of a fungicide of such concentration as to inhibit germination remain dormant, and may germinate when the fungicide is removed.

(3) In estimating the value of a fungicide, by testing the germination of spores after they have been submitted to its action, it is necessary to keep the transfers under observation for several days, even in the case of spores which normally germinate within a few hours.

(4) In the case of thick-walled spores, the fungicidal value of copper sulphate is small.

(5) Spores of the same fungus vary enormously in their power of resisting the action of toxic agents, so much so that it is not possible to find an approximately constant time in which the spores would be killed by immersion in a solution of given percentage. It is only possible to give a maximum limit, and this could only be obtained by an extended series of tests. Single experiments may be quite misleading.

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COCONUT PALM DISEASES.

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TRINIDAD, B. W. I.

The serious Coconut Palm Diseases in Trinidad.

Within recent years at least five different investigators have studied the diseases of the coconut palm on the Island of Trinidad and they have arrived at different conclusions. Unfortunately none of these workers carried on their investigations to the length of establishing all the facts necessary to substantiate their theories as to the cause of the trouble. In view of these incomplete researches and the diverse conceptions of the maladies it is impracticable to give satisfactory recommendations as to methods of control or eradication. It is very possible, however, that by carefully comparing the observations of the various investigators some more uniform conclusions can be reached. The writer studied the conditions in the coconut groves of Trinidad after acquiring a good knowledge of the groves of Jamaica and Cuba. Before this work the reports of J. H. Hart* and F. A. Stockdale† on the diseased palm were carefully perused, and, since then, the reports of O W. Barrett‡ and of Dr. Fredholm§ upon the same topic. As the point of view of these various workers has been different from that of the writer, and especially as their interpretation of certain phenomena connected with the disease is at variance with his, it is desirable to call attention to these points. In discussing the condition of the trees, only the one or more diseases that cause their death will be considered.

The earliest investigator, Mr. Hart, reported, in 1905, that on "La Retraite" estate, Cedros, diseased trees were found to be infected from the ground upward, the stem showing a ring of red discoloration lying between the woody exterior and the cellular interior. The discoloration became more prominent toward the growing point and appeared especially at the base of the leaf-stalks, and at the base of the embryonic spathes enclosing the floral organs. These all eventually became quite putrid, the leaves fell, and the tree gradually died. Great quantities of bacteria as well as fungi were found in the affected tissues. Mr. Hart did not commit himself as to the cause of the trouble, but forwarded some of the material to the Imperial Department at Barbados, whence it was sent to the Department of Agriculture at Washington. Here I had the opportunity of examining it, and am able to corroborate Mr. Hart's statement that the growing point was full of bacteria. In the particular specimens which I have now mounted as microtome sections on glass slides, bacteria only are among the cells, there being no signs whatever of fungi.

Mr. F. A. Stockdale investigated the diseased coconut palms in the fall of 1906. He reported on two maladies which completely

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* Bull. Miscellaneous Inf., Bot. Dept. Trinidad, Oct. 1905, p. 241.

† Trinidad *Royal Gazette*, Feb. 14, 1907, pp. 349 to 363.

‡ Rept. to the Agric. Soc. of Trinidad and Tobago, Soc. Paper No. 280.

§ Dr. A. Fredholm, Proc. Agric. Soc. Trinidad and Tobago, Vol. 9, March, 1909, Pt. 3, pp. 159 to 172. Soc. Paper No. 367.

destroy the palms; one of which he called the root-disease, and the other the bud-rot. He described the root-disease as one in which the trunk shows the red discoloration toward the outside for considerable of its length, and the decayed roots and the petioles are infected with a fungus. Eventually, when the vitality of the tree has been reduced, the terminal bud becomes involved in a soft rot and the putrid mass then falls over and the tree dies. In describing the bud-rot Stockdale says the roots appeared to be healthy, the stems showed no signs of the discoloration but the bud was involved in a vile sort of bacterial rot and eventually fell over. In the advancing margin of the rot usually were only bacteria, but in a few cases there was some fungous mycelium. Mr. Stockdale concluded that the root-disease was due to fungi and the bud-rot to bacteria. According to his descriptions trees suffering from the root-disease differ from those affected by the bud-rot only in having discolored trunks, diseased roots, and affected petioles, the rotting bud being common to both cases.

Mr. O. W. Barrett in 1907 reported that of the diseased trees of the island, about ninety-five per cent. were affected with the root-disease reported by Mr. Stockdale and only a very few cases were affected by bud-rot. Unfortunately no notes are given as to the appearance of the diseased trees, so that Mr. Barrett's conception of these maladies is uncertain.

Dr. A. Fredholm presented before the Agricultural Society an article published in March of the present year. He described a serious disease in which the trunk was normal and the roots usually so, while the terminal bud became disintegrated into a sour smelling, whitish, semi-fluid mass which, when examined under the microscope, was seen to be swarming with bacteria. The adjacent tissues, out to the petiole bases, were traversed by fungous mycelia, which Dr. Fredholm believed to be the forerunner of the bacterial rot. He states that he considers Stockdale's root-disease and the foregoing disease distinct, chiefly for the reason that he has never found the decay of the roots and the discolored stems present in the affected trees which he examined. He further states that he found a few cases of what was supposedly bud-rot, *i.e.*, putrid terminal bud full of bacteria and entirely lacking in fungi. To substantiate his statements Dr. Fredholm obtained successful fungous infections (small spots), but he made no bacterial inoculations.

My own observations in Trinidad confirm the ideas of the foregoing writers in regard to the general symptoms of the trouble affecting the coconut palms of that island; the drooping and yellowing leaves, the premature falling of the nuts, the putrid condition of the bud, and the occasional occurrence of fungi on the bases of the petioles, the diseased condition of the roots, and a red discoloration of the trunks.

As regards the cause of these troubles of the palms, Hart states merely that both fungi and bacteria are present in the advancing margin of the rotting tissues of the crown. He does not commit

himself as to the cause of the disease. Stockdale believed the root-disease to be due to fungi and the bud-rot to bacteria. He came to these conclusions after discovering, in cases of the root-disease, some mycelium in the decaying roots, in the discolored trunks, and in the bases of the petioles. The rotting bud full of bacteria he considered secondary when these other symptoms were present. In the case of the bud-rot he found this putrid mass at the crown to be filled with bacteria, and only rarely to contain some fungous filaments, while the conditions typical of the root-disease were absent; he, therefore, concluded the bud-rot was probably due to bacteria as has been claimed by workers in Cuba and elsewhere.

Fredholm believed that those trees in which the bud had become disintegrated into a putrid mass, swarming with bacteria and surrounded by tissues traversed by fungous mycelia, were primarily affected by the fungi which prepared the way for the bacterial soft-rot action. He found some trees with this soft rot but in which no fungous mycelium was to be seen and for that reason admitted the probable ability of the bacteria to produce primary infection.

The conclusions of Stockdale and Fredholm appear entirely unwarranted from the observations which they have reported. Because fungous mycelium is found in the decaying tissues of a plant is not sufficient reason for stating those fungi to be the cause of the decay. Stockdale describes the soft rot of the crown which eventually occurs in the root-disease, and states that it is a different sort of rot from that in the bud-rot disease. He claims that lowered vitality or mechanical injury may produce such a rot, without, however, citing any experiments to prove this. It is, however, contrary to my own experience. I have wounded many trees through the heart tissues, have seen many trees eaten in the crown by insects, and others suffering extremely from some evil condition of the soil, but in none of these I have in mind has the soft rot developed. It might possibly develop along with an unhealthy condition of the growing point but I do not believe it is a natural sequence, such as Stockdale indicates. His description of the soft rot in the root-disease corresponds exactly to that of the bud-rot, and should be considered a symptom of the latter trouble. Whether the soft rot may be due to various causes, is a different matter. Whether there are various accompanying conditions is another question. The fact remains that in Stockdale's root-disease and in the well-known bud-rot there is a soft-rotted condition of the bud which causes the death of the tree. This must be essentially one and the same disease. In cases of the bud-rot in Cuba, Jamaica, Trinidad, and British Guiana, I also have found fungous mycelium at the base of the petioles and in the roots, but always, I believe, as a secondary phenomenon, and no more than was to be expected. If the tree is lowered in its vitality for any reason it becomes an easy prey to infection by various saprophytic organisms.

The same sort of criticism applies to Fredholm's treatment of his fungous disease. As he describes it, the bud is resolved into a soft-rotted mass, swarming with bacteria, and the surrounding tissues

are traversed by fungous mycelia. Fredholm considers the fungi as forerunners of the soft-rotted condition. He may be correct but he presents no proof that such is the case. The soft rot in the crown can apply only to the one disease, *i.e.*, the bud-rot. As to whether or not fungi are the forerunners of this disease is an entirely different question. We must get clearly in mind the idea that the term bud-rot applies to any case in which the bud of the tree is reduced to a soft-rotted mass which is swarming with bacteria. It is the decay of this bud which causes the death of the tree. Fungous mycelium in the petiole or in some of the hundreds of roots of the tree will not soft rot the terminal bud. In few of these cases described by Stockdale and Fredholm was the mycelium very abundant, but, on the contrary, was usually scarce and occasionally difficult to find.

These investigators found in all cases of seriously diseased trees a putrid condition of the crown in which were abundant bacteria and, in addition, they found on some trees fungous mycelium on the roots, on the trunk, or in the bases of the petioles. In the diseased trees in which any fungous mycelium was found to be present, both Stockdale and Fredholm attributed the trouble to the fungus, notwithstanding the presence of bacteria in the soft-rotted crown; on the other hand, the trouble was admitted to be due to the bacteria only when no other organism was found in the diseased parts of the tree.

After comparing the various reports referred to in this article, it would seem quite clear that the only destructive disease of the coconut palm in Trinidad has the one characteristic of the rot of the growing point or bud of the tree, and from the foregoing discussion of the descriptions it is evident that it is the well-known bud-rot common to various parts of Tropical America and to the Eastern Tropics.

It has not yet been proved what organism is the cause of the bud-rot, although generally admitted to be due to bacteria. The identification of diseases passing under different names as all one form, will, however, do much to facilitate the solution of the cause of the trouble. To know that Stockdale's root-disease and Fredholm's fungous disease and the bud-rot are all phases of the same malady, will, I am sure, greatly simplify the work. The frequently accompanying fungi may well give rise to the question as to whether or not general unhealthy conditions of the tree may furnish opportunities for bacterial infection. Such conditions may be caused not only by the presence of fungi, but also by unsuitable soil, or by unfavourable climatic conditions. As these factors are subject to partial control, herein lies an opportunity of treating trees affected with bud-rot, provided the disease is induced by these conditions. On the other hand, if the fungi are secondary and if the unsuitable surrounding conditions are not necessary to the successful production of the bud-rot, the infection with bacteria can then be considered as the primary symptom and treatment can be made with that in mind. If the rot is bacterial the disease can be controlled

only by destroying most of the distributing organisms. Thus a thorough knowledge of the cause of the death of the tree, together with various accompanying conditions will enable the investigators to limit their plans to but one line of the work instead of making elaborate preparations for the control of the various conditions which are found to be but phases of the one disease.

It is urged that conclusions as to the cause of the disease should be proved by infection experiments. Stockdale made no experiments which brought about the death of the tree from fungous inoculation. Fredholm secured some successful fungous inoculations but they did not cause the death of the tree. I have obtained good fungous inoculations on the leaves and in these cases the spread of the disease was shown in the drying and browning of the tissues, but never to the extent of killing the tree. In addition I have made bacterial inoculations which produced soft, white rots, such as are found in the typical bud-rot. In several cases where these bacterial inoculations were left for some months, the death of the trees eventually took place. The specific organism has not yet been successfully isolated, but as long as the artificial soft-rot can readily be secured from bacterial cultures, completion of the work is but a matter of time.

While differing with the conclusions of the other investigators, acknowledgment must be made of the value of their observations. A thorough understanding of the accompanying conditions is necessary to the successful development of a method of control of any disease. It is seldom sufficient that such a work be conducted alone from the point of view of a botanist or mycologist, but the observations of an entomologist and a bacteriologist are also desirable.

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BUD-ROT OF THE COCONUT PALM.

JAMES BIRCH RORER.

Trinidad, B.W.I.

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The Bud-rot of the Coconut Palm.

A disease of coconut palms now generally known as bud-rot from the fact that its culmination is the complete rotting of the terminal bud has killed during the last fifty or sixty years large numbers of trees in the West Indies and adjacent Central and South American countries. Though the disease was first reported in the early part of the last century it attracted no great attention until the early eighties when it caused serious losses in some of the large plantations of Cuba. Since that time bud-rot has been found on nearly all of the islands and has been studied by the pathological workers connected with the various Colonial Departments of Agriculture and by several members of the United States Department as well. A disease with the same characters has been found in a number of places in the East and described in the agricultural journals of India, Ceylon and the Philippines.

Bud-rot is characterized by the yellowing and drooping of the leaves, the falling of the immature nuts, the wilting, breaking over, and browning of the terminal leaf, and the putrid condition of the whole region of the cabbage. The disease may kill a tree very quickly if the point of first attack is near the bud itself, but when the older outer leaves are the first parts attacked the tree may live for some time before it finally succumbs. Though various theories have been put forward from time to time as to the cause of bud-rot it is now generally admitted that it is of bacterial origin, and that the putrid parts of dead and dying trees serve as a source of infection of healthy trees.

As reported to the Board of Agriculture at the November meeting the writer has found bud-rot, similar in all respects to that which has almost destroyed the coconut industry of Cuba, in various places here in Trinidad. Though spraying with Bordeaux mixture and Paris green or arsenate of lead may serve as a protection to young cultivations from infection with bud rot, thorough sanitation is the best means of combatting the disease in older plantations. In this sanitation the essential point is to destroy as quickly as possible all infectious material such as the rotted bud, the bases of leaves and flower stalks, the flower sheaths, and the upper portion of the stem, all of which are teeming with bacteria. This may be done by burning in the dry season but in rainy weather burying should be resorted to.

Many coconut planters believe that flaming the crowns of diseased trees will free them of the disease, and this method of treatment is practiced extensively in some places. In cases where the basal part of the outer leaves alone are attacked and the infection has not become deep seated, it is quite possible that the invading bacteria may be killed by the heat from the flaming, but it does not seem possible that trees in which the disease has reached the terminal bud or the young surrounding leaves can be saved by this method of treatment. Flaming

has been practised during the past year on Mr. Gordon's Laventille estate, so that some idea of the value of this method of treatment may be gained there within the next few years.

As the coconut bud-rot has gained a foothold here in Trinidad, every means should be taken to combat it before it becomes too widespread. The Board of Agriculture has already voted the sum of $500 for this purpose, and the work of cutting down and destroying diseased trees has been begun and is being pushed forward as rapidly as is possible. The work was started in the Laventille district on November 30, and to date (January 8), 1,151 dead or dying trees have been cut down. The trees which had evidently been dead for a long time and which were hard and dry have been cut into junks and piled for burning, while all which were at all green or in which there was any evidence of soft rot were buried wholly or in part The writer hopes that all diseased trees on the island may be destroyed in this way within the next six months.

Mr. Plummer, Agricultural Inspector, has been given immediate charge of this sanitation work, and he has pushed it forward very rapidly and tactfully as well.

To make this work of any lasting value however it is essential that a Coconut Palm Protection Ordinance be passed which will make it possible to force property owners to destroy coconut trees which subsequently become diseased. An inspector could then be appointed whose duty would be to see that the Ordinance was rigidly enforced.

The following paper entitled "The Serious Coconut Palm Diseases of Trinidad" by J. R. Johnston, Assistant Pathologist, U.S. Department of Agriculture will undoubtedly prove of interest to the coconut growers of the Island, by some of whom at least the author is known personally. Mr. Johnston has devoted almost his entire attention during the past four years to the study of coconut diseases, especially the bud-rot. Though most of his work has been done in Cuba he has carefully studied the diseases of the coconut in Jamaica, Trinidad, and Demerara so that his experience has been wide. The present paper of Mr. Johnston is a criticism of the various reports on coconut diseases in Trinidad which have been published during the past few years.

As will be seen his studies have led him to different conclusions from those of some of the other workers on these diseases. He considers that the death of palm trees resulting from the soft rotting of the cabbage must, in practically all cases, be attributed to bud-rot, a disease primarily caused by bacteria, rather than to the attacks of one or more fungi which accompany the rot or are found on the leaves or roots of dying trees, while the others have considered bud-rot a minor disease here, restricted to a few localities, and the soft bacterial rot of the cabbage, in the majority of cases, simply a secondary symptom of diseases caused by fungi.

Inoculation experiments with fungi or bacteria suspected of being parasitic are essential in establishing the cause of both plant and animal diseases. From a lack of such experiments much confusion has arisen in regard to the various diseases of the coconut palm, as can be readily seen from a reading of the literature on the subject. The writer knows that Mr. Johnston has produced bud-rot by artificial inoculation. It is to be hoped that the complete report of his work will soon be published, and will clear up some of the doubtful points in regard to this and other coconut diseases.

JAMES BIRCH RORER,
Mycologist.

[*Reprinted from West Indian Bulletin, Vol. IX, no. 4, pp. 361-81.*]

FUNGUS DISEASES OF COCOA-NUTS IN THE WEST INDIES.

BY F. A. STOCKDALE, B. A. (Cantab.), F.L.S.,

Mycologist and Agricultural Lecturer on the staff of the Imperial Department of Agriculture.

The fungus diseases of cocoa-nuts have attracted considerable attention during the past few years, and careful investigations have been made. In the *West Indian Bulletin*, Vol. VI, pp. 307-21, a collection of literature available to that date on the diseases of cocoa-nuts in the West Indies was published for the information of those interested.

The bud-rot disease of the cocoa-nut has been investigated in Jamaica and Cuba, and had been reported from Trinidad and British Guiana. A visit was made to Trinidad in 1906 to investigate the diseases of cocoa-nuts. Twenty-nine estates besides numerous peasant properties were inspected, and trees receiving different kinds of cultivation, growing under varying conditions of soil and climate, were examined. Practically the whole of the cocoa-nut area of Trinidad was covered, and several fungus diseases were carefully investigated. Three distinct diseases were found, two due to attacks of fungi, and one of bacterical origin, similiar to the bud-rot disease in Cuba. Specimens of diseased cocoa-nuts have also been carefully examined from British Guiana, and preliminary reports have been made, while in 1908 a cursory examination was made of some diseased cocoa-nut material at the sixth West Indian Agricultural Conference held at Jamaica.

Diseases of cocoa-nuts have also recently received attention in Java, Ceylon, and India. This paper will deal with the diseases of cocoa-nuts investigated in Trinidad, being a summary of the general preliminary report submitted to the Government of that colony. This report was published in the *Official Gazette* and has been reprinted in pamphlet form by the Agricultural Society.

Three diseases that have been found to occur in the West Indies are:—

1. ROOT-DISEASE investigated in Trinidad and from specimens received from British Guiana. Possibly this also occurs in some parts of Jamaica, and a similiar disease has been described by the Imperial Mycologist for India in Travancore.

2. LEAF-DISEASE was investigated in Trinidad and is apparently very similiar to a disease reported from Java.

3. BUD-ROT was found to occur in a few cases in Trinidad, and is also, doubtless, to be found in British Guiana, Jamaica, and Cuba. It is now under careful investigation in Cuba, where it has occasioned wide-spread damage.

ROOT-DISEASE.

An attack of this disease is generally first shown by the leaves. They show a slightly wilted appearance, then turn yellow, first at the tips and then gradually all over the leaflets. These dry up, blacken, hang down from the 'cabbage,' and often remain for a considerable time before they are shed—a badly attacked palm often being entirely enclosed in numbers of leaves around its trunk. Frequently, however, it is noticed that the leaves do not hang down around the trunk, but the petioles break across, leaving the sheathing portion on the trunk while the foliage portions of the leaves have fallen to the ground. Sometimes the petiole does not completely break, and the foliage portion of the leaf hangs vertically downwards attached to the portion of the petiole that is left attached to the stem.

The outer leaves are sometimes those that show signs of wilting and yellowing first, but this is not always so, for frequently palms may be noticed in which a 'middle' ring of leaves becomes wilted and yellow, while rings of green leaves remain above and below.

After the yellowing of the leaves, trees bearing a good crop of nuts, as a rule gradually shed most if not all of them, irrespective of their size and stage of development, and the flowers subsequently produced do not set. In fact, it is possible for a person to pick out with certainty, trees that are diseased before any yellowing of the leaves is noticed, by carefully looking at the condition of the leaves and at the latest flowers that are being put forward. Any trees that are diseased can at once be singled out. The local conditions of the soil must be considered before a tree is definitely stated to be diseased, as the whole appearance of the diseased trees suggests a lack of water, and, therefore, may be confused with trees that are suffering from this cause alone in drought-affected areas.

After a number of the leaves have yellowed and died, it is only a question of time before the terminal bud becomes a putrid mass,* and falls over, and the palm eventually dies.

SEQUENCE OF EVENTS IN THE DISEASE.

Trees which only present external signs of disease to the experienced observer show that apparently the roots are probably the parts which become first affected. After a considerable number of these have been rendered useless in contributing to the life of the plant, changes take place which result in a sour-smelling, red discoloration in the stem that probably commences at the level of the ground and extends upwards.

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* When a cocoa-nut palm is affected by any disease or pest, the terminal bud, in the advanced stages of the disease almost invariably becomes involved in a rot. This must not be confused with the bud-rot disease. This appears to be a specific disease, and the roots, stem, and leaves are sound, while the bud is in a diseased condition.

The position of this red discoloration would appear to vary in the stem directly with the roots that are affected, and it has been repeatedly noticed that when a 'middle' ring of leaves shows signs of yellowing, the discoloration is found towards the centre, while if the lowest leaves become wilted, the stem presents a ring of discoloration towards the outside of the stem. The petioles also show that they are infested with the mycelium of a fungus, for when the leaves become dry and hang down, the fructifications push through the epidermis and form pustules of varying size and shape. Eventually, when the vitality of the tree has been reduced, the terminal bud, as already mentioned, becomes infested with a 'rot,' which causes the whole 'cabbage' to fall over, resulting in the death of the tree.

MICROSCOPIC EXAMINATION.

Specimens of leaves, roots, stems, petioles, etc., were taken from a considerable number of diseased trees for examination, and for cultural and infection experiments.

In a diseased root, the walls of the cortex cells appear to be shrunken and the cells are turgid no longer. Between the walls of consecutive cells can be seen large, dark-coloured, septate hyphae, while many of the cells themselves have become invaded by the same. When a cortical cell is threatened by the approach of a fungal hypha, its cell contents appear to become altered, for large yellowish globules make their appearance. Whether these have been produced by the cell itself as a means of protection against the fungus, was not definitely determined, but after the mycelium has gained an entrance into the cell, these globules, as well as all the other cell contents are destroyed and absorbed.

The fungus spreads from one cell to another by piercing through the cell walls, and soon obtains an entrance into the thin-walled cells of the xylem parenchyma, and eventually into the xylem vessels themselves.

The red discoloration of the stem was carefully examined microscopically, but, except in the case of trees that were very badly diseased, few fungal hyphae could be detected. Those observed in the advanced cases of disease were similar to those noted in the roots, but it is most probable that the red discoloration of the stem is primarily due to the disorganization of normal functions through the stoppage of supplies from the roots.

It was observed also that, almost without exception, the petioles of the leaves of badly diseased trees showed a large number of minute ruptures of the epidermis, after they had died and had fallen to the ground. The petioles in varying stages of disease were therefore submitted to a careful microscopic examination, and it was observed that a mycelium of a fungus was found in all diseased petioles.

The point of the first attack could not be determined, but that part of the petiole just where it expands to ensheath the stem of the tree, is the part where the effect of the fungus is first noticed. The whole petiole gradually assumes

a blackish colour, the leaflets become brown, and eventually on the dead petioles, fructifications burst through the epidermis just where it begins to expand before ensheathing the stem. These pycnidia give off a black, powdery dust which consists of the spores of the fungus. These are of two kinds—the one single-celled and colourless, and the other two-celled and brown.

DETERMINATION OF FUNGUS.

The two-celled spores suggested that the fungus belonged to the genus *Botryodiplodia*, and specimens were forwarded to Dr. N. Patouillard, for identification. He reported as follows:—

'I have examined the specimens of parasitic fungi on petioles of cocoa-nut.

'The epidermis is raised and split but covers the fungus. Out of the slit, a black powder, which is formed of brown, uniseptate spores protrudes. If a section is made through the wart-like pustules, there is found under the skin a black cellular stroma filled with several pockets. These spaces are filled with colourless, non-septate spores. If these are placed in a damp chamber, in about twenty-four to thirty-six hours, germination takes place. The colourless spores are therefore adult and mature. If we consider the fungus in respect to its hyaline spores, it must be considered a *Cystospora*, or better a *Fusicocum*.

'If the brown, septate spores really belong to it and are the final end of the development, the fungus will be a *Botryodiplodia*. It remains then to establish that these last belong to the fungus. It is very probable but not proved.'

In working out the life-history of the fungus it has been frequently observed that the colourless spores become brownish in colour and afterwards septate. Considering that no difference can be noted in the mycelia produced by the two fungi, that the pycnidia bear both kinds of spores, and that the colourless cells have been observed to divide by a single septum and then become brown, it may be concluded that the septate, brown spores are the final production, and that the fungus must be considered as a species of *Botryodiplodia*.

EFFECT OF FUNGUS.

The damage caused by the fungus in the roots by the disorganization of the cortex and other cells has been observed, and therefore the effect this has on the cocoa-nut plant may clearly be understood. A reduction in the water-absorbing power of the root system takes place, and less food substances are elaborated.

Young trees do not appear to suffer to any considerable extent, for numerous instances have been noticed of young plants having quite a healthy appearance while a number of the roots were in a diseased condition. When, however, the fruiting period comes on, a large drain is made upon the tree. It is taxed very highly and, if the roots are diseased, wilting

and yellowing of the leaves are noticed. It was observed that trees that were just coming into bearing were the most liable to succumb.

GENERAL OPINIONS AS TO THE CAUSE OF THE DISEASE, ETC.

The general opinion of the planters of cocoa-nuts was that this disease is due to the weakness of the plants produced by the setting of immature nuts. In some districts, histories of weather-beaten cargoes of green nuts having been driven on the shores and the nuts used for planting purposes were held out as the cause of the trouble. This disease, however, was not limited to a few scattered trees, and evidence distinctly points to its being infectious. A tree that has become attacked by the disease is sooner or later surrounded by a large number of others showing signs of the disease. In one portion of the Cedros district, the disease has been noticed making its way gradually into other fields of cocoa-nuts farther south. It is, therefore, impossible to believe that the large areas of cocoa-nuts in Cocorite, Laventille, Guapo, Cedros, and the interlands of Mayaro were planted with immature nuts.

Moreover, the fungus found in the roots and in the petioles of diseased trees is capable of attacking vigorous trees. Anything that tends to reduce their vitality would considerably help along the fungus. Circumstances which retard growth, both of the root and shoot system give the root fungus a much better chance. This was conspicuously brought to my notice on a portion of an estate in the Cedros district. A low-lying hollow showed that a large quantity of water was present in the soil. Such a condition was unfavourable to good development of the trees; they were stunted in growth and showed that root development was not very large. The clayey, impervious nature of the soil suggested that an elaborate system of drainage was needed in order to procure the aeration necessary for vigorous plant growth. In this hollow, most of the trees had died out very rapidly and the disease had soon spread from this portion of the estate to other parts where the soil conditions were more favourable. Trees on sandy soil on higher ridges were often noticed to be attacked, but it was generally in low-lying, undrained hollows that the disease was the worst. This is also seen in the Guapo and Mayaro districts.

These examples should suffice to show how natural peculiarities of an estate and other physical features affect the disease. But these alone cannot be sufficient to cause the death of the trees, as is often urged. The characters of the soil affect the growth of the plant and they may also affect the fungus, and, therefore, it is necessary to keep the condition of the soil as good as possible, in order that it may be favourable to the growth of the plant.

The death of the trees in some districts appeared to be very rapid. Three or four months is generally the time that intervenes between the first external symptoms and the death of the tree, and usually within another three months a ring of diseased trees is noticed around the dead stump. In another district, the disease is much less prevalent and the death of

diseased trees does not take place so rapidly, for in places where two trees are growing from the same hole, the death of the second usually takes place from nine to twelve months after the death of the first.

NATURAL INFECTION AND SPREAD OF THE DISEASE.

Samples of soil from around the roots of diseased trees have been investigated microscopically, and sterile mycelium was found. This would suggest that the mycelium is capable of spreading through the soil. This mycelium may be capable of attacking and killing the youngest rootlets and then entering into the larger ones. The entry of the mycelium into the roots is still an unsolved problem, but evidence tends to show that the larger roots first show signs of infection where the smaller rootlets join them. In no case has the mycelium been noticed on the exterior of the roots, and it would seem that it has to depend upon the rot of the smaller roots for its distribution.

The roots of several young supplies that were planted upon or near to the place where diseased trees have been removed, showed on examination, the presence of a mycelium within them, but not in sufficient quantities to cause their death. This indicates that infection can take place through mycelium. Infection experiments have been conducted in the laboratory of the Imperial Department of Agriculture, and in the field in Trinidad, which show that the fungus is parasitic in habit and can attack healthy cocoa-nut tissue.

It would appear to be probable that the disease may spread:—

(1) By mycelium through the soil from root to root.
(2) By spores blown from tree to tree.
(3) By germinating tubes of spores from petioles, attacking either the roots of the same tree or the roots of another.
(4) By germinating 'chlamydospores' from decaying petioles.

The best conditions for the germination of the spores depend upon the presence of suitable quantities of air and moisture, and spread of the disease would be expected to be the most rapid when the conditions are favourable.

The spread of mycelium in the soil depends a good deal upon the cultivation. Any condition of the soil that is unfavourable to the cocoa-nut may favour the root disease by hindering free root development. Excessive moisture and excessive drought may be favouring conditions for the disease. The latter cannot be remedied except by irrigation, and does not appear to be a factor of any importance in this disease. The former—excessive moisture—is noticeable in many of the low-lying portions of the estates. In these hollows, the soil is often of a clayey nature—impervious to water—and, therefore, many of the air spaces between the soil particles are replaced by water. The normal working and growth of the roots are interfered with and the destruction of such roots by fungal

mycelium may speedily follow. The effects of excessive moisture can be lessened by careful attention to drainage, and to the mechanical condition of the soil.

REMEDIAL MEASURES.

Although the complete life-history of the fungus and its method of spread are not yet known with certainty, it would appear that owing to its habit of penetrating and spreading in the living tissues of the root of the host plant, cure is practically outside the question when a large majority of the roots are permeated with mycelium. Therefore it is probable that only the most drastic measures are likely to provide permanent relief.

It cannot be expected that the disease can be entirely eradicated; but, by a method of what is known as 'stamping out,' the amount of disease may materially be reduced and the fungus kept in check.

There are six principal ways in which we may hope to attack this disease. These are:—

(1) Destruction of all diseased material.
(2) Isolation of diseased areas.
(3) Resting of infected land before planting 'supplies.'
(4) Spraying and application of chemicals.
(5) Improved cultivation and drainage.
(6) Searching for and propagating disease-resistant varieties.

Destruction of all Diseased Material.

It has been observed that diseased petioles that have fallen to the ground often bear large numbers of spores. This would indicate that the fungus in the petioles is capable of living upon dead matter, i.e., is saprophytic during some stages of its life-history. Young supplies, planted on the place whence dead trees have been removed have also been noticed to be affected, and old stumps that have been left standing have become permeated with fungal mycelium. These instances show that there is sufficient food in the form of decaying vegetable matter in old trees, etc., to continue the life of the fungus and, therefore, all dead or diseased material in an infected area should be entirely destroyed and not left to accumulate.

(*a*) All dead and dying trees should be cut down, and burnt whenever that is possible. When the trees contain a large amount of sap and still bear a fair number of green leaves, it is almost impossible to burn them, unless a number are collected and burnt in a pit after the manner of 'charcoal fires.' Otherwise these trees should be cut up and buried deeply with lime. The adoption of the burning method would probably prove to be the most effective, but experience will show whether it is the most practical.

(b) All diseased leaves and petioles that have fallen to the ground should be collected and immediately burned on the spot.

(c) On no account should rubbish, such as husks, etc., be allowed to accumulate in any infected area, for this may prove beneficial to the growth of the fungus, which may continue to live on it, and thus it would form a base from which the disease can spread to living trees.

(d) The basal portion of the diseased trees and as many diseased roots as possible should be destroyed. It may be expensive to 'grub up' these stumps, but when it is borne in mind that the fungus can live in the old roots and is liable to attack young supplies, as well as probably to spread through the soil to healthy trees, such a destruction is necessary. An old East Indian cocoa-nut authority* holds that a large number of the roots of a cocoa-nut tree may be destroyed by cutting the tree near to the ground, leaving the stump for some time to dry, and then building a heap of trash and forming a fire (preferably closed by putting a thin layer of soil on the top) over the remains of the stump. In this way, he states, most of the roots will be destroyed, for once the fire has obtained a good hold it will travel for some distance down the roots.

There is also another danger of leaving old trees and rubbish about the plantation,—they offer sufficient food for beetles, etc., which may increase rapidly and become a source of danger.

It is necessary that all cultivators of cocoa-nuts should combine and have all diseased material destroyed, for it is useless for any planter to keep his estate clear of all disease while his neighbour neglects trees which become a permanent source of infection. Only the most energetic action is likely to prove beneficial, for it has been observed that there is a marked tendency for the disease to spread from certain centres of infection.

Isolation of Diseased Areas.

The disease generally appears, at first, in small patches, while the surrounding trees are apparently unaffected. As the mycelium of the fungus may spread through the soil, these diseased areas may be isolated by cutting trenches from 1 foot to 18 inches deep around them. It must be remembered that the mycelium may have spread further than is noticeable on the trees and, therefore, the trench must be made to include several trees that are apparently healthy, and care should be taken to throw the excavated soil into the diseased portion and

* All about the 'Cocoa-nut Palm,' Ferguson, Ceylon, p. lxxxiii. We have no experimental evidence of the value of this suggestion in practice, but it might be given a trial in the dry season when the weather conditions are favourable.

not outside it. Such a method of isolation, especially where the diseased areas are small, cannot be too highly commended in dealing with root diseases; but the amount of success depends entirely on the thoroughness with which the work is carried out. In any case it may prove to be a very good method of confining the disease to a limited area.

Resting of Infected Land before Planting Supplies.

Young supplies that have been planted in infected land have shown that they have been attacked by the fungus, and therefore it would appear necessary to rest such land for a series of years after the removal of diseased material before commencing to replant. In this way it is hoped that the fungus mycelium may be starved out. At the same time it affords an opportunity for careful cultivation of the land. Such land should be turned up, either with the plough or with the fork, so that the fungus mycelium may be turned up and exposed to the destructive action of the sun, and when supplies are put in they should not be planted in the old rows, but rather between them, so that the new plants alternate in chess-board fashion with the spots whence diseased trees have been taken.

The careful cultivation of the land before replanting should improve the condition of the soil, and possibly green dressings of leguminous plants might be profitably grown and ploughed in. Some of the soils are already rich in organic matter, and here some remuncrative rotation crops might be grown on badly infected lands for a year or two before planting the young supplies.

Spraying and Application of Chemicals.

When diseased trees are cut down and destroyed there may be fungal mycelium left in the soil. As pointed out previously, a good deal of this can be destroyed by exposure to the action of the sun; but it can also be destroyed, to a large extent, by the use of lime. The lime should be, if possible, unslaked, as in this state its fungicidal powers are far greater than when it is slaked. It should be applied before forking or ploughing, and the amount to be used must depend upon local conditions, and upon the extent of the disease. The fungicidal powers of good lime have not yet been sufficiently realized, and besides, there is improvement of the condition of the soil on account of clay flocculation, and of the fertility of the soil on account of the rendering available of dormant plant food.

A method of preventing death of forest trees, etc., from root diseases in France is to lay bare the base of the trunk and as many roots as possible, and to apply quantities of sulphur or ferrous sulphate.

The spraying of diseased trees with Bordeaux mixture may also prove beneficial in destroying spores of the fungus on the petioles, and applications to surrounding trees might prevent them from becoming infected by spores blown by the wind.

Improved Cultivation and Drainage.

It has been noticed that the disease is the more destructive in undrained land. Stagnant water should not be allowed to remain in the soil, as this tends to hinder healthy root development and also favours the spread of the fungus. It would appear that water may be present at the roots of the cocoa-nut to almost any extent, but the necessary condition is that it should not be stationary. Proper drainage not only relieves the soil of excess of water, but also allows greater root development to take place, and thus secures the plant against effects of drought.

The cultivation of land under cocoa-nuts is, as a rule, neglected, and instances have been noticed where old plantations have been giving smaller yields of nuts, that have been gradually diminishing in size, year after year. Better cultivation and drainage would offer more favourable opportunities for the cocoa-nut, and would be of considerable value in dealing with the root disease, especially in wet areas with soil of a clayey nature. It would afford a better chance for the plant to make use of plant food, either from the soil or from manures. (The evidence of a planter in the Cedros district, which shows returns of 120,000 nuts per year from an area that gave 40,000 nuts per year five years previously through judicious applications of manures, emphasizes the fact that the cocoa-nut readily responds, in some soils at least, to liberal applications of manures.) It also would be expected that the condition of the trees would be considerably improved. By encouraging healthy growth and increasing the vigour of the trees, they will be able better to withstand the attack of the fungus.

Searching for, and Propagating, Disease-resistant Varieties.

A good deal of work has been done in combating plant diseases by selection of disease-resistant varieties, and therefore it may be a matter of the greatest importance to make further observations in this direction, as the selection of a resistant race of cocoa-nuts may prove of the utmost importance in combating this disease. During my visits through the different parts of the island, I made careful observations and inquiries in this direction, but I am unable to say with confidence whether any varieties of cocoa-nuts are disease-resistant. Several planters state that a variety known as the 'Green Spanish' is very hardy and is able to withstand attacks much longer than other varieties. From personal observation in the badly diseased districts it would appear as if all varieties are attacked, but, if every cocoa-nut planter would note the comparative resistance of the various varieties, considerable advance in this direction might soon be made.

In conclusion, it should be stated that in cases where the fungus has completely devastated large areas, the trees should not be allowed to stand and rot, for these would only be nurseries for the development and spread of the disease, and seeing that such varying conditions of soil and climate, etc., exist in the cocoa-nut districts, it is not supposed that all the remedial

measures suggested will be applicable to every plantation. Therefore it must be left to the planters themselves to choose those which they, from local experience, think to be the most applicable to their own particular conditions. The destruction of all diseased material on systematic lines, however, should be practised by all, for it is expected that by such co-operation the injury would soon be mitigated to a large extent, and the disease kept well in hand.

RESULTS OF REMEDIAL MEASURES.

Reports have periodically been received from those areas of Trinidad where this disease is most prevalent. Several of the large planters have co-operated in a systematic adoption of the remedial measures above given, with the greatest success. On the larger properties the disease is now said to be well under control, and it is hoped that the smaller proprietors also will adopt similiar measures. Destruction of all diseased material and an improved system of drainage and cultivation have apparently successfully checked the spread of the disease.

LEAF DISEASE.

GENERAL CHARACTERS OF THE DISEASE.

Many trees are noticed which have leaves that appear to be drooping, and with the tips of the distal leaflets of a greyish colour. An external examination of the leaflet shows that whereas the tip is quite dry and dead and that many parts of the edges of the leaflet are in a similar condition, there are small yellowish spots, more or less regular in shape, which may be observed to increase in area (spreading centrifugally from a point in a more or less circular manner), scattered about the leaflet. These areas may be observed to increase gradually in size, and not infrequently to run into one another, forming irregular blotches, which often eventually cover the greater portion of the surface of the leaflet.

During the growth of the spots, they gradually change from a yellowish colour to a greyish white, and each is bordered by a margin which is of a dark colour, generally an intense greenish-brown. At first, therefore, it is easy to recognize the various 'diseased spots,' for in each the oldest part is always in the centre, and proceeding outwards from this, each successive ring has been more lately attacked than the last. This can be seen by the fact that the centres of the spots always become grey first, while rings of yellow of varying degrees of intensity can be noticed outwards from this grey centre.

By careful observation it will be noticed that the discoloration more often appears on the under side of the leaflet first, but the pale yellow, and later the greyish discoloured areas, are equally evident on both surfaces. This is due to the disappearance of the chlorophyll, and the subsequent death of the cells comprising the tissue of the leaflet, as the diseased areas are generally sunken through, being thinner than the healthy portions.

It would appear that the tips of the distal leaflets show the effects of the disease first, although an examination of an affected leaflet shows that diseased areas are scattered all over its surface. From these distal leaflets, the disease appears to spread gradually to those nearer the stem, and often when all the leaflets on the terminal 2-3 feet of the leaf have been attacked, and appear in a dry, withered condition. this portion of the leaf breaks down, if the leaf happens to be floating in the air in a position between the vertically upright and the horizontal. This end of the leaflet rarely falls to the ground, but remains hanging to the healthier portion. and is very characteristic of the disease.

If, however, the leaf is older before it is attacked, i.e., hanging between the horizontal and the trunk of the tree. the tip does not often break. This shows that the breaking of the tips of the leaves is due to the weight of the diseased portion itself, and is, therefore, due to natural causes. Many trees were examined that showed leaves with their tips broken off and hanging down in this manner, and all showed that they had disease spots distributed throughout their leaflets.

The yellowish spots that are characteristic of the disease in such cases are found in the greatest abundance on the distal leaflets, but eventually all the leaflets become attacked.

After a time, when a large number of disease spots have made their appearance, the whole leaf assumes a yellowish appearance and gradually becomes greyish and withered. This may remain hanging to the trunk for a considerable time, but finally it drops. In the early stages of the disease, only a single leaf may be attacked, but usually several are noticed on every diseased tree. As a result of the diseased condition of the leaves, the number of nuts borne on the later-developed flower-stalks diminishes, and finally no flowers set. When a large number of leaves have been badly attacked, the terminal bud is left standing alone, and it is only a question of time before this falls over, and the death of the palm results.

Close examination of the upper surface of the leaf of one of the disease spots when it has assumed the grey colour shows minute pustules. They are blackish-grey in colour, and are irregularly distributed, often being very numerous. They are more or less oval in shape and suggest that the upper cuticle of the leaf has been raised. This can be shown to be so, for if a diseased leaf that has fallen on the ground where sufficient moisture is present, be examined, it will be observed that these small pustules rupture, usually by a triangular slit through which the greyish spores protrude.

MICROSCOPIC EXAMINATION.

Specimens of leaves, roots, stem, etc. were taken from diseased trees for microcospic examination and, whereas the roots and stem appeared to be quite normal, the leaves were in a diseased condition. By cutting a transverse section through a diseased spot while still yellow, there could be noticed, by careful staining, a delicate, septate, branched

mycelium, occupying the intercullar spaces and running between the cells. These eventually become pushed apart from one another by the invasion of this mycelium from which minute branch-like structures are sent off into the cells themselves. They may possibly act as *haustoria* or sucking organs. Finally these branches appear to grow, and eventually the cells and vessels of the leaf become invaded with mycelium which probably causes the death of the invaded patches. The margin of the diseased spot is characterized by a ring of dark colour, and examination shows that here the mycelium of the fungus is only intercellular, and that the filaments end in this dark margin. This may mean that the leaf is responding to the unnatural irritation caused by the invasion of the fungus, and is probably secreting some substance with which to protect itself.

When the diseased spot becomes grey and dry, the minute pustules on their upper surfaces begin to make their appearance. These small pustules bear the spores of the fungus.

INFECTION EXPERIMENTS.

The infection experiments leave no doubt that this leaf fungus may be weakly parasitic, and show that infection can take place by the germination of the spores, the germinal tubes of which can pass through the stomata of the leaf, and through wounds of any kind on the leaf surface. No result, however, was obtained when the spores were placed on the upper surface of an uninjured leaf, which may indicate that these germinal tubes are incapable of penetrating through the epidermis of the leaf.

DETERMINATION OF FUNGUS.

Recently, a report on a disease of cocoa-nuts caused by *Pestalozzia Palmarum*, Cke., by Dr. Charles Bernard, has come to hand from Java. Differences occur in the description of the disease from Cuba (*West Indian Bulletin*, Vol. VI, p. 313) and that from Java. In Cuba, the fruiting bodies of the fungus are described as being emitted from the under surfaces of the leaves, whereas in Java the fructifications occur on the upper surface only. The distribution of the disease in Java appears to be limited to young plants, and seems to do the most damage when the young plants are beginning to take root in the ground, after they have exhausted most of the stored material from the endosperm of the seed.

Despite certain differences in the appearance and size of the spores of the fungus found in Trinidad and that described from Java, the germination of the spores appears to be similar, and many symptoms of the disease in Trinidad are identical with those described in Java.

I am of the opinion that the Trinidad and Java fungi are merely geographical varieties of *Pestalozzia Palmarum*, Cke., and not distinct species.

NATURAL INFECTION, ETC.

During the short time that was given to the investigations of this disease, evidence could not be obtained on the time it takes from first infection by germination of a spore to the production of a yellow spot on the leaf, nor on the time it takes for spores to be produced; but the following information on this point has been obtained during the work of Bernard on a similar disease in Java:—

> 'Two very vigorous cocoa-nut trees, situated near a diseased plantation were isolated, and in the crown of one was placed a bunch of badly diseased leaves. After two months (this is the period of time that is generally considered to be the "period of incubation" of the disease, i.e., the time which intervenes between the moment that infection takes place and that when the first exterior manifestations of the disease appear) this tree showed the characteristic spots upon its leaves, spots which grew and caused three months later (i.e. five months after infection) the death of the tree. The adjoining tree, which was not infected, remained healthy and vigorous.'

There can therefore be no doubt as to the cause of the disease or to the ease with which it can spread, for this parasite, as seen by the above experiment, is the primary cause of the disease, and is not a secondary appearance on plants in bad condition.

It would appear however, that the leaf, after succumbing to the numerous drains upon its resources, falls to the ground before the mycelium has obtained the possible limit of its development; for if a leaf that has fallen into a dry place be placed in a moist chamber, a multitude of pustules bearing conidia will be produced within forty-eight hours, while if a leaf that has fallen in a damp place, where it is shaded from the effects of the sun, be examined, large numbers of spores can be seen to be given off, thus showing that the mycelium is capable of further growth after the leaflet has fallen to the ground.

EARLY OPINIONS AS TO THE CAUSE OF THE DISEASE.

Evidence on the cause of the disease was gathered from planters of cocoa-nuts, but, as in the root diseases, the general opinion was that it was due to the weakness of the plants, produced by setting immature nuts, or to improper soil conditions. It is impossible to believe that a large portion of an estate in the Mayaro district or isolated patches in the Icacos district would be planted by immature nuts alone, for the disease does not appear upon a single tree here and there. As to improper soil conditions, it is generally held that favourable conditions of soil are necessary for the growth of strong, vigorous, healthy plants, and therefore every effort should be made on the part of the planter to understand the different soil conditions of his estate, and to assist nature whenever

possible. This is the most perplexing question with which the planter has to contend, requiring judgement that can be gained only by many years of practical experience.

From experiments previously mentioned there can be no doubt as to the fungoid nature of the disease, and measures for combating its ravages will be considered later. The spread of the disease certainly appears to be influencd by the age and condition of the plants, and therefore improved cultural methods are of paramount importance.

EFFECTS OF FUNGUS IN THE PLANT.

The primary damage done by this fungus has been seen to be the destruction of the cells of the internal tissues of the leaflets. This destruction continues if the conditions are favourable for the fungus, and gradually the leaf-area of the plant is reduced. Under extremely favourable conditions, many of the leaves become entirely destroyed, through the mycelium from a large number of disease-spots spreading throughout the whole of the interior of the leaf. When this happens, the whole of the leaf-area of the plant is destroyed, the terminal bud falls over, and the tree eventually dies.

At other times, large numbers of disease spots are scattered about the leaves, but not in sufficient quantities to cause the death of the plant. These spots, however, have been rendered, through the destruction of the chlorophyll of the leaf, useless to the plant, and, therefore, the plant becomes gradually weakened.

To the planter, the most important of the checks is that given to flower development. Less flowers are produced, and finally the diseased condition of the trees becomes marked in the shortness of the crop of nuts. Again, food is cut off from the development of nuts, their size diminishes, and their saleable value becomes reduced.

It has been noticed that in some instances the shortage of crop, etc. can be traced directly back to the damage done by the leaf-fungus. In some cases where the 'disease-spots' are few in number, little damage was noticed, nor do they seem to increase until the conditions become unfavourable to healthy growth of the host plant.

It would appear, therefore, that this fungus is a weak parasite, and is only capable of doing appreciable damage when the conditions are extremely favourable for its development.

The fungus that is present on cocoa-nuts in Java is also a weak parasite, and there the damage seems to be limited to young plants just after being planted out, when they are sending out roots in search of food for themselves after having used up all the stored material of the endosperm of the seed. Therefore, if the conditions are such as to promote healthy, vigorous growth in the cocao-nuts, the fungus may be overcome and its attack, for a time at least, thrown off.

REMEDIAL MEASURES.

A consideration of the life-history of the fungus and the relation between it and the cocoa-nut suggests the remedial measures likely to be effective in dealing with the disease. The measures suggested can only aim at the reduction of the amount of the disease and at keeping the fungus well in check, for it would be impossible to suggest treatment that will entirely eradicate it. The remedial measures must be divided under two heads :—

(1) Those which will destroy or weaken the fungus, and

(2) Those which encourage a more vigorous growth of the cocoa-nut, so as to enable it better to withstand any attacks of the fungus.

(1) The spores of the fungus, under favourable conditions, exist in such numbers that unless these are destroyed it is possible for the disease, given warm and moist, or windy weather, to spread very rapidly :—

(*a*) All dead trees should therefore be cut down, all the portions carefully collected on the spot where the tree once stood, and the whole *burnt*. Great care should be exercised in collecting the portions of diseased plants, and the burning should be done in the diseased area of the field, for if diseased leaves are carried or dragged about the field, there is much danger of spreading the disease. Although it is only the leaves and petioles that are diseased, it would be wise to burn as much of the tree as possible in order to prevent decaying stumps being left about the plantation to become infected with other diseases and pests.

(*b*) Trees that are showing a few diseased leaves should be climbed, and the diseased leaves cut down and burned. The manager of the estate of Icacos has burned several trees that have shown signs of disease, by sending a boy up the tree, packing dry material in the lower leaf-sheath bases and setting fire to the whole. This method, in some instances, has given good results, for all the lower diseased leaves and all the fungus spores were destroyed. Considerable damage, however, is often done to the tree by this method, and at least two or three crops of nuts are destroyed. It would probably be just as effective to cut down the diseased leaves and burn them on the ground, for in this way damage by burning would not be done to the young parts at the terminal bud.

(*c*) It would be advisable to search through the plantation to see whether any isolated trees show the characteristic broken-tips of the leaves with the pustules on them, and if such are found, these trees should be marked on the stem with a suitable mark so that they can be carefully watched, as they may possibly be the source of infection for another area. All leaves showing signs of disease should be destroyed

with fire, and such trees should be examined at least once every fortnight until no further spread of the disease is observed. These trees should be carefully attended to, manure should be given them and the soil around them properly tilled, in order to enable them to throw off the attacks of the fungus.

(*d*) If the disease continues to spread, spraying with fungicides would render the spores of the fungus incapable of germination, and would therefore be effective in keeping the disease in check. The fungus is most easily assailed through those portions of it that come to the surface—the spores, for their germination can effectively be prevented by the use of chemicals; but the problem remaining to be solved is how frequently is it necessary to apply such an external remedy. Without further information such a question cannot be answered, but continued observation would soon reveal an answer to this important question. How soon after complete destruction of the spores will a fresh batch be produced on the same leaf? This is the question to be answered, and such an answer must be a guide to the frequency of the use of fungicidal spraying.

Bordeaux mixture would probably be the fungicide that would be used most economically, and spraying with this would need a spray pump, and a long hose attached to the pump. The nozzle may be tied to the end of a long bamboo, or a boy may be sent with it up the tree in order that the highest trees could be sprayed. All trees showing any signs of disease and any in their immediate neighbourhood should be sprayed at frequent intervals, and thus most of the spores would be prevented from germinating

(2) It has been noticed that this disease, at present, is doing serious damage only when the conditions of the soil and cultivation are unfavourable to healthy plant growth, and, therefore, in order to keep the cocoa-nut palms in vigorous growth, such points as drainage, manuring and cultivation should be carefully attended to. In the interlands of the Mayaro district, which are low-lying and often water-logged, the conditions could easily be improved by a system of drainage. The soil there is of a clayey nature, and is somewhat impervious—not soil the most suitable to sucessful cocoa-nut cultivation. Some of the land is below the sea-level and, therefore, it is impossible to obtain an outflow for the surplus water; but much of the surface water and that in the top 6 or 9 inches of the soil might easily be removed by the digging of a system of wide drains about 18 inches deep. Even draining such a portion of the soil would prove beneficial to the cocoa-nut trees, as they feed mainly by roots in the top layers of the soil and therefore the removal of an accumulated mass of 'sour' water should prove to be an incentive to further root formation.

Moreover, here, as on the estate in Icacos district, where the diseased areas appear to be on the light dry soils, the

question of manuring and cultivation of the soil should be carefuly attended to. Manures must not be looked upon as a means of curing disease, but they may be the means of strengthening the growth of the plant, and the problem of manuring should be solved by the best resources at the command of the estates.

A SECOND FUNGUS IN THE LEAF DISEASE.

When diseased leaflets have become dry, and when the wart-like pustules of *Pestalozzia* have made their appearance, there can frequently be noticed (besides the grayish-black pustules of *Pestalozzia*) small, round spots that are quite black. These black spots appear to follow the veins of the leaflet and are usually to be seen in the greatest numbers on the lower surface of the leaflet near the mid rib. They are also frequently seen on the lower surface of the leaflet and the flower spathes and, some times, the petioles are covered with black spots, the individuals of which are just visible to the unaided eye, but as a whole, often appear as a blackish incrustation.

On the leaflets where the black spots are seen, the greyish colour noticeable in the case of the *Pestalozzia* is marked by a dark-brown colouration in the case of this second fungus. This appears to be due to dark-coloured mycelium in the dried-up tissues of the leaflets. In no case has the presence of this second fungus been observed on leaflets that had not been previously attacked by *Pestalozzia*. It would, therefore, be concluded that this second fungus is only of secondary importance. Infection experiments, etc., would tend to show that it can attack leaflets that have previously been weakened by attacks of *Pestalozzia*, but until further experiments have been conducted, it is impossible to say whether it is a direct parasite or not.

IDENTIFICATION OF FUNGUS.

The fungus must be referred to the *Fungi Imperfecti*, and on account of the character of the pycnidia and the spores, it must be referred to *Macrophoma* if the unicellular spores are considered mature and final, or to *Diplodia* if the two-celled brown spores are the final results of development.

It is possible that this fungus may be similar to that lately described by Emerson from Bowden, Jamaica, and is identical in the *Macrophoma* form with *Sphaeropsis palmarum*, Cooke, from petioles and mid ribs of cocoa-nut from Demerara, and in the *Diplodia* form with *Diplodia epicocis*, Cooke, from dead young leaves of cocoa-nut.

DISTRIBUTION AND REMEDIAL MEASURES.

This fungus has been found in Icacos, Cocorite, and the Mayaro districts, and seems to be closely associated with the leaf disease and, therefore, until further experiments can be conducted to inquire into its exact habit, the remedial measures suggested for the leaf disease should be sufficient to keep it in

check. Whenever it should be noticed without the *Pestalozzia* of the leaf disease, similar remedial measures should be employed and should undoubtedly prove beneficial in preventing its spread.

It is hoped that before long further information can be given about the habit of this fungus, and then more definite recommendations can be made.

BUD-ROT DISEASE.

In having trees felled that were showing signs of the root disease in the Cedros district, a tree was sometimes found which did not show the symptoms characteristic of the root trouble. The roots appeared to be healthy, the stem showed no signs of red discoloration, while the bud was involved in a vile smelling sort of bacterial rot. It was reported that about 1 per cent. of the diseased trees in this district showed signs of a bud trouble, but that they were seldom met with except as isolated cases. On visiting a small savannah planted in cocoa-nuts in the Siparia district, it was noticed that the trees were in a diseased condition. The youngest leaves appear to stand upright and do not unfold as they should. Afterwards, they turn yellow and then brown in colour, and the whole appearance is that of a withering tree with the centre of the cabbage in an unhealthy condition. Sometimes this dying of the 'central bud' could not be noticed until many of the lower leaves had turned yellow or brown, nor did there appear to be any regular succession of deaths of the lower leaves, for often the lowest leaves were the first to turn yellow, while at other times the 'middle' leaves showed the first signs of being unhealthy.

After a time the terminal bud falls over, frequently leaving a ring of quite healthy-looking leaves at the top of a 'headless' trunk.

On cutting down several of these trees, it was noticed that while the roots and stem were perfectly healthy, the bases of the youngest leaves and their wrappings were in a rotten condition, as were also the bases of the still unfolded flower stalks. This rot, in a diseased palm that is still standing, is invisible until the harder outer coverings of the bud are removed and it is found to be limited to the softer tissues. Instead of finding a healthy white cabbage, a pale-brown, rotten mass is seen. It extends in badly diseased trees from the bases of the youngest leaves for a distance of 3 or 4 feet downwards until it reaches the harder tissues of the stem. Sometimes it spreads in thinnish lines, which can often be noticed externally by the leaves of one side of the tree turning yellow, while the others are apparently healthy, but at other times it seems to spread centrally, and the varying external symptoms must be accounted for by the assumption that the rot has no set method of spreading, and, therefore, whatever leaf has its food supplies cut off first must show the first signs of withering and yellowing.

A badly diseased bud is generally full of fly larvae, etc., and the smell is awful. It resembles closely the bud of a tree badly attacked with root or leaf disease and, therefore, suggests

that further researches are greatly needed before any definite conclusion about its origin can be arrived at.

Microscopic examination of the roots and stem indicated that they were quite normal, while those portions of the terminal bud, in the advancing margin of the disease, showed in most cases bacteria of different kinds, but in two instances the advancing margin was marked by a reddish discoloration produced by some fungal mycelium. Although this mycelium has been more or less successfully isolated, fruiting bodies have not been obtained nor have the few infection experiments given positive results. Of the bacteria, two have been isolated in pure cultures, while at least one more has been observed in a rotten bud. Two of the bacteria are apparently gas-producers and have been found in rotten terminal buds of trees that have suffered from the leaf disease or the root trouble, while another has only been noticed in rotten buds from the Siparia district.

Whenever the youngest visible leaf is observed to be lopped over and wilting, the terminal bud is sure to be involved in a soft rot. The roots and stem appear to be quite healthy and no evidence of damage to the tree could be found.

The few isolated cases in the Cedros district would indicate that this disease is not of a very infectious character, but large numbers of trees have been killed out in the Siparia district, the spread of the disease being very rapid and apparently from the windward. I am inclined to the view that this disease is similar to the destructive disease of cocoa-nuts in Cuba; but, as far as Trinidad plantations are at present concerned, it would appear to be largely due to unfavourable conditions of soil, drainage, etc.

Weakly trees, whether caused by bad drainage, inferior cultivation or inferior soil are the most likely to be those that are attacked by disease, and therefore improved conditions of cultivation, etc., should render the trees more capable of withstanding attacks.

REMEDIES.

More prolonged study and much experimental work are necessary to demonstrate conclusively the cause of the disease. With our present knowledge of the nature of the disease it is impossible to suggest a remedy for trees that are already infected, and, therefore, steps must be taken for preventing its spread.

The rapidity with which the trees have been killed in the Siparia district, and the marked resemblance of this disease to that which has proved such a menace to the cocoa-nut industry of Cuba, should illustrate the need for vigorous action being taken in order to prevent further spread of the disease.

All diseased trees showing only the 'bud-rot' should be cut down and destroyed. If the planter is sure that it is only bud-rot and not root disease (which is characterized by the disorganized condition of the cortex of the roots, and by the reddish ring of discoloration in the stem) it should be sufficient to cut off the top 4 or 5 feet from the diseased trees

and bury deeply with lime (it would be found impossible to burn such rotten masses as diseased buds). The remainder of the trunk and all rubbish should also be collected and burned, or otherwise these may serve to harbour other pests, which eventually may become destructive. The felling and destroying of diseased trees is undoubtedly an expensive process, but the neglect of these precautions may make all the difference between a trifling loss of trees and a serious epidemic

It is also necessary that united action should be taken, for it is useless for one planter to care for his estate and destroy all diseased material while his neighbours allow the disease to multiply and their estates to become centres of infection.

From observations made in the Siparia district, it would appear that any variety of cocoa-nut tree may be attacked, but it would be advisable to look diligently for plants that are resistant to this disease, for the selection of the most hardy varieties may be a means of assisting better cultivation, destruction of all diseased material, etc., in dealing with this disease.